

Collection and Analysis of Weekend/Weekday Emissions Activity Data in the South Coast Air Basin

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What is the Weekend Effect?

Emissions of ozone precursors tend to be lower on weekends (WE) than on weekdays (WD).

However, in many cities, WE ozone concentrations now tend to be equal to or higher than WD concentrations.

This paradox—*the weekend effect*—appears to be growing more common and spreading geographically over time.

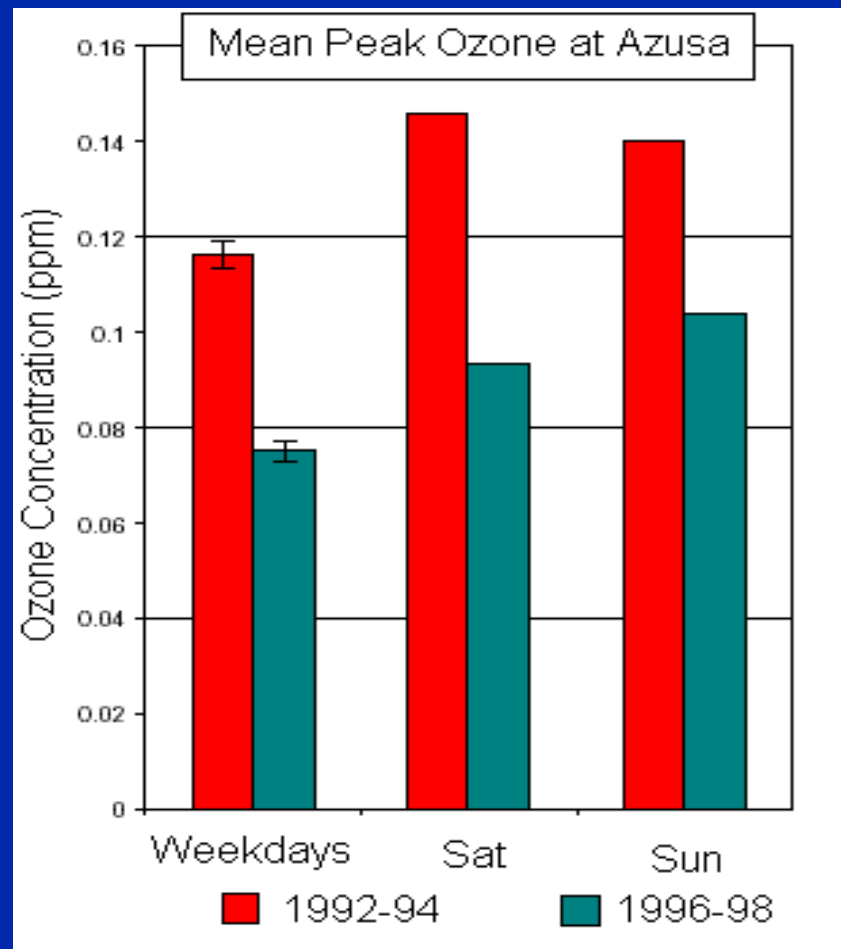
The Weekend Effect in Los Angeles

Los Angeles ozone air quality improved from 1980 to 1999.

- Number of 1-hr exceedances decreased from about 150 to only 50 per year.

WE peaks = WD peaks.

- From 1980-1999, WD-WE difference became more pronounced.



Source of figure: Austin, J.; Tran, H. "A Characterization of the Weekend-Weekday Behavior of Ambient Ozone Concentrations in California." Draft staff report prepared by the Technical Support and Planning Division, California Air Resources Board, Sacramento, CA, 1999.

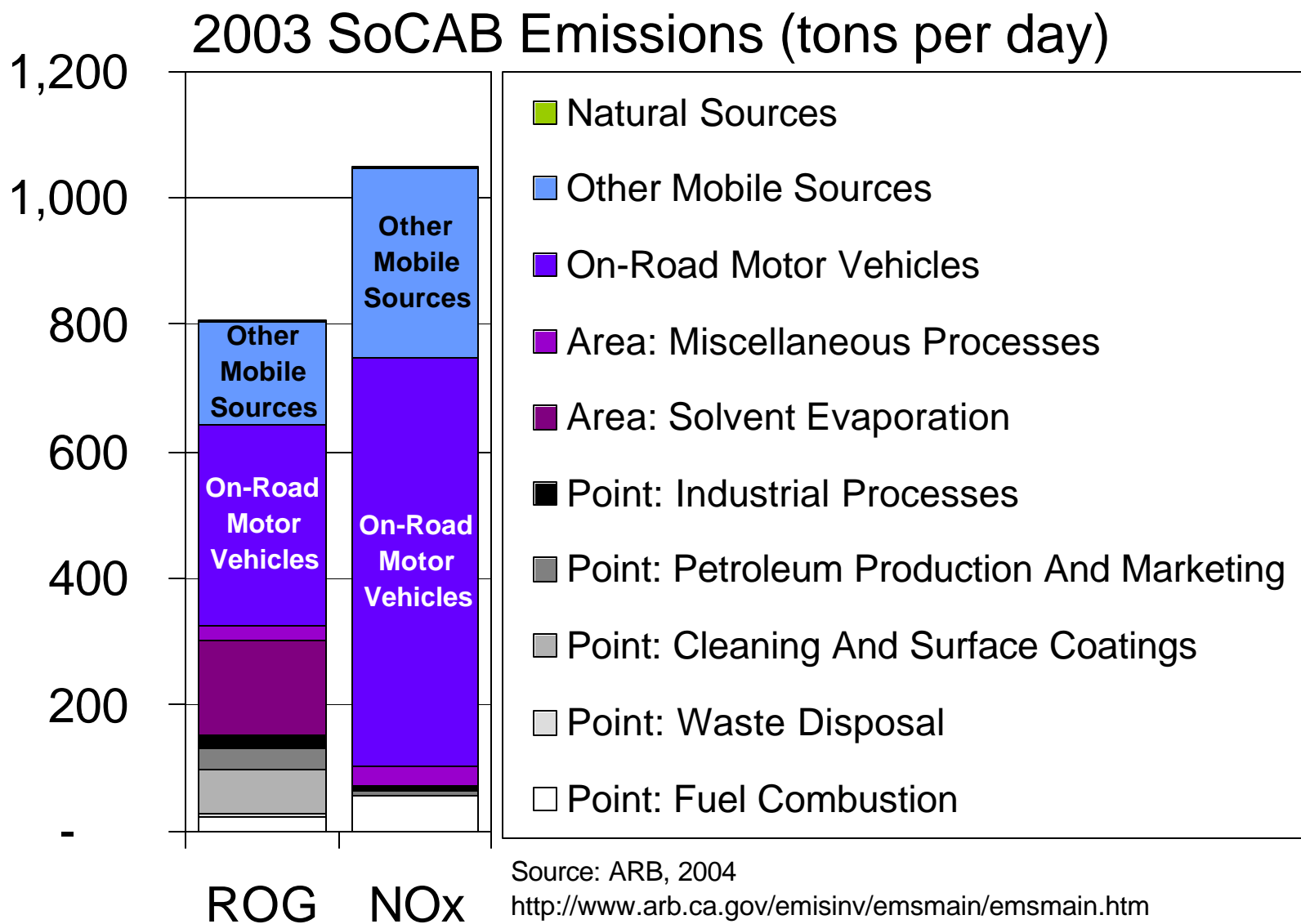
Purpose and Objectives

Purpose: Address a lack of WE-specific emissions data, which are needed to support air quality modeling exercises for WE conditions in Los Angeles.

Objective: Characterize WD-WE activity patterns for a variety of emissions sources in Los Angeles.



Importance of On-Road Mobile Sources



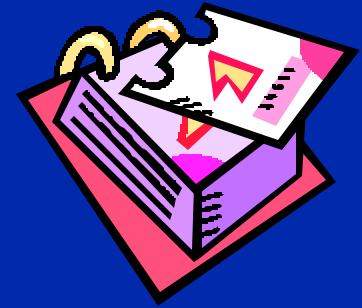
Brief Overview – Methods

- Apply an array of methods (e.g., surveys, in-vehicle instruments, etc.) to directly measure activities for a variety of emissions source types.
 - On-road mobile sources
 - Non-road mobile sources
 - Area sources
 - Major point sources
- Direct the majority (80%) of effort and resources to on-road mobile sources.



Brief Overview – Findings

- Traffic activities follow predictable weekly patterns.
 - Vehicle-miles traveled (VMT)
 - Frequencies of soaks or trips
 - Speed distributions
 - Types of roads driven
 - Fleet distributions (heavy-duty versus light-duty)
- Some residential activities—especially recreational activities—tend to increase on WEs.
- Business-related activities and emissions from major point sources tend to decline dramatically on WEs.

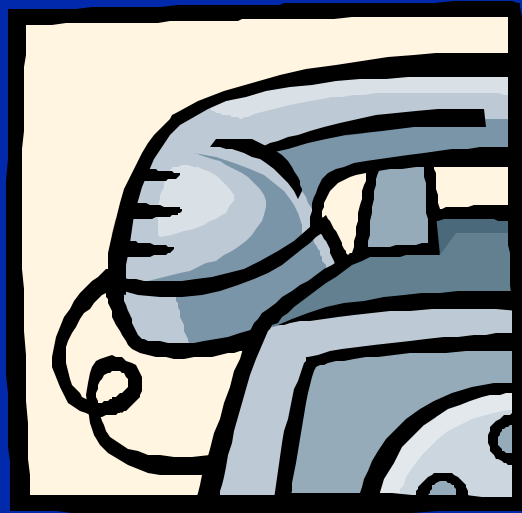


Presentation Overview

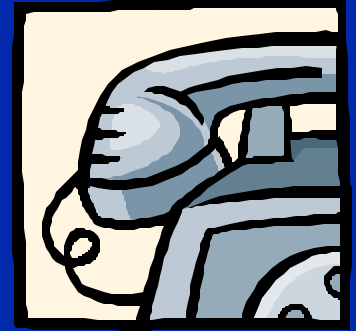


- Data Collection Methods and Highlights of Findings
 - Telephone and mail surveys
 - Instrumented vehicle study
 - Surface-street traffic counters
 - Caltrans weigh-in-motion (WIM) traffic volumes for freeways
 - Continuous emissions monitoring systems (CEMS) data for major point sources
 - Special studies of neighborhoods near air quality monitoring sites
- Recommendations
- Closing Remarks and Acknowledgments

Telephone and Mail Surveys



Survey Participation



- Participants were recruited randomly throughout the SoCAB or from specific, targeted neighborhoods.
- Results for the randomly selected groups and the targeted neighborhoods were comparable.
- Compared to past experience, refusal rates were typical or low for residential and businesses surveys.
- All participants completed telephone questionnaires; some completed daily activity diaries by mail.



Daily Activity Diaries

CARD 1 DAILY ACTIVITY SURVEY FOR: FRIDAY

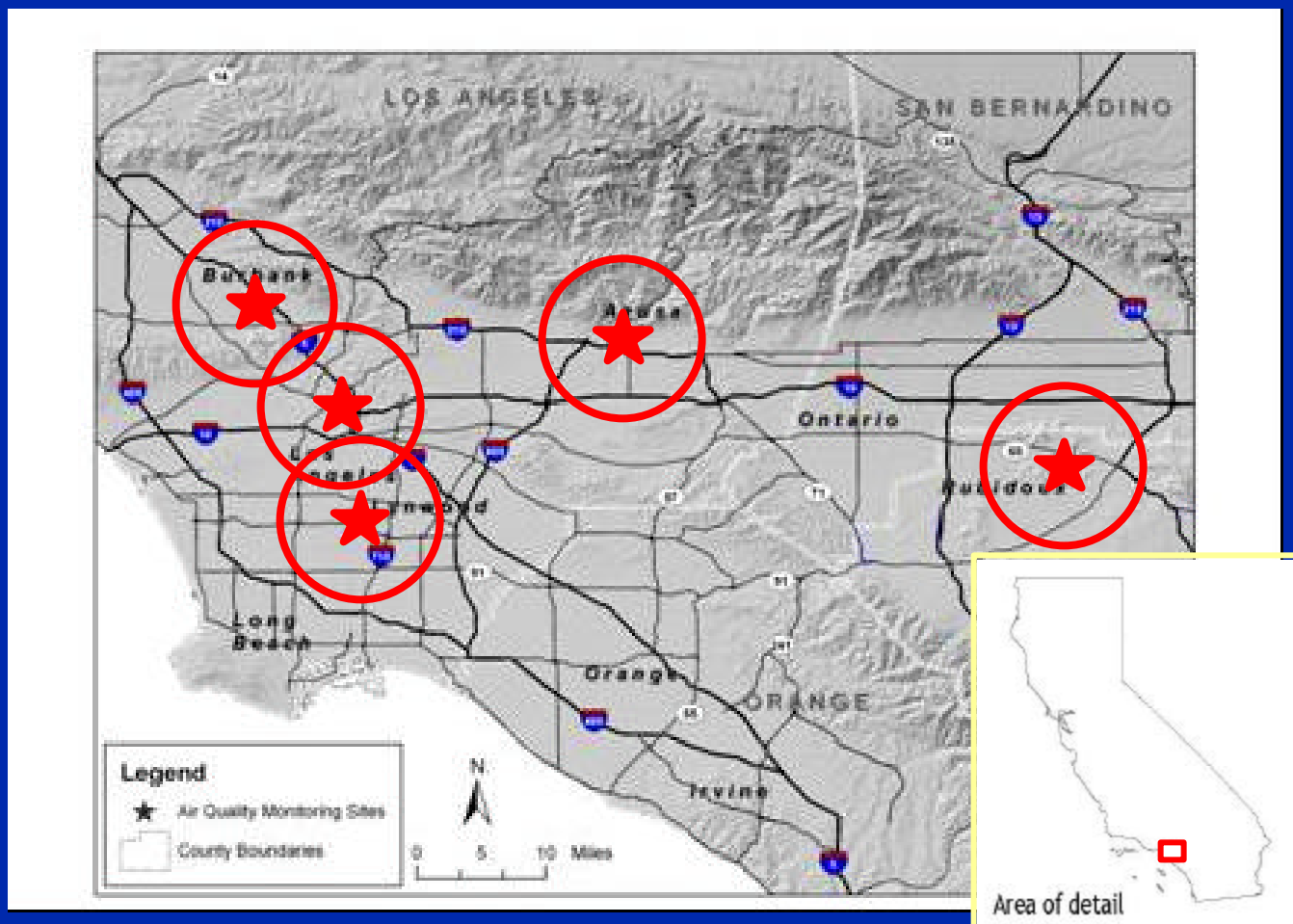
1. Was a barbeque grill used at your household today? ☐ Yes ☐ No
When? (check all that apply) ☐ Morning ☐ Afternoon ☐ Evening Total minutes used?
2. Please check if items were used at your household today, and indicate when they were used:
☐ Paints, varnishes, stains, thinners, solvents, or degreasers ☐ Morning ☐ Afternoon ☐ Evening
☐ Consumer products (hair sprays, dyes, nail polishes, polish removers) ☐ Morning ☐ Afternoon ☐ Evening
☐ Took a shower or bath (with warm or hot water) ☐ Morning ☐ Afternoon ☐ Evening
☐ Clothes washer or automatic dishwasher (using warm or hot water) ☐ Morning ☐ Afternoon ☐ Evening
3. How many times did a passenger vehicle depart from your household today? 0 1 2 3 4 5 More than 5 times
When? (check all that apply): ☐ Morning ☐ Afternoon ☐ Evening
4. How many times did you start a vehicle at your household without driving it today? 0 1 2 3 4 5 More than 5 times
5. Did any household member use a recreational watercraft today (such as a boat, jet ski, or other)? ☐ Yes ☐ No
When? (check all that apply) ☐ Morning ☐ Afternoon ☐ Evening Total hours used?
6. Did any household member use an off-road recreational vehicle (such as an ATV, dirt bike, or 4-wheel drive)? ☐ Yes ☐ No
When? (check all that apply) ☐ Morning ☐ Afternoon ☐ Evening Total hours used?
7. Did you consider today a ☐ Work day ☐ Holiday/vacation day off ☐ Regular day off (Please check one)
8. Your answers to the questions above apply to **FRIDAY** on what date? _____
9. Are you completing this card on the same date that you just entered on line 8 above? ☐ Yes ☐ No
10. If NO, what date did you complete this postcard? _____

Survey Participation

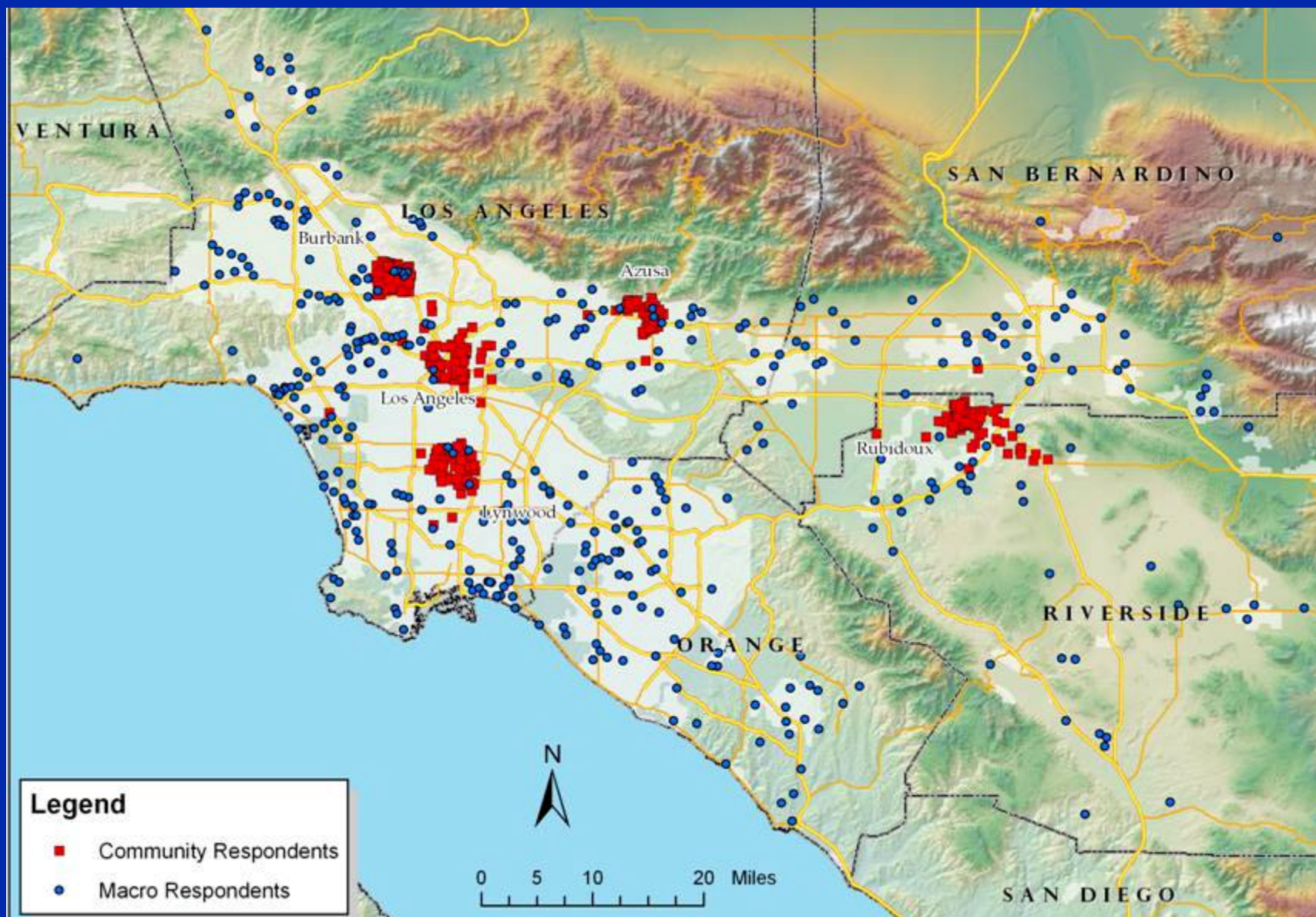
Group	Areas	No. Respondents		Refusal Rate
		Telephone Survey	Daily Activity Diaries	
Households	Targeted and random	870	488	41%
Small businesses	Targeted	137	<i>n/a</i>	14%
Construction businesses	Random	258	<i>n/a</i>	25%

Survey Participation

Targeted neighborhoods were near key air quality monitoring sites in the SoCAB.



Survey Participation – Households



Survey Results – Household Activities

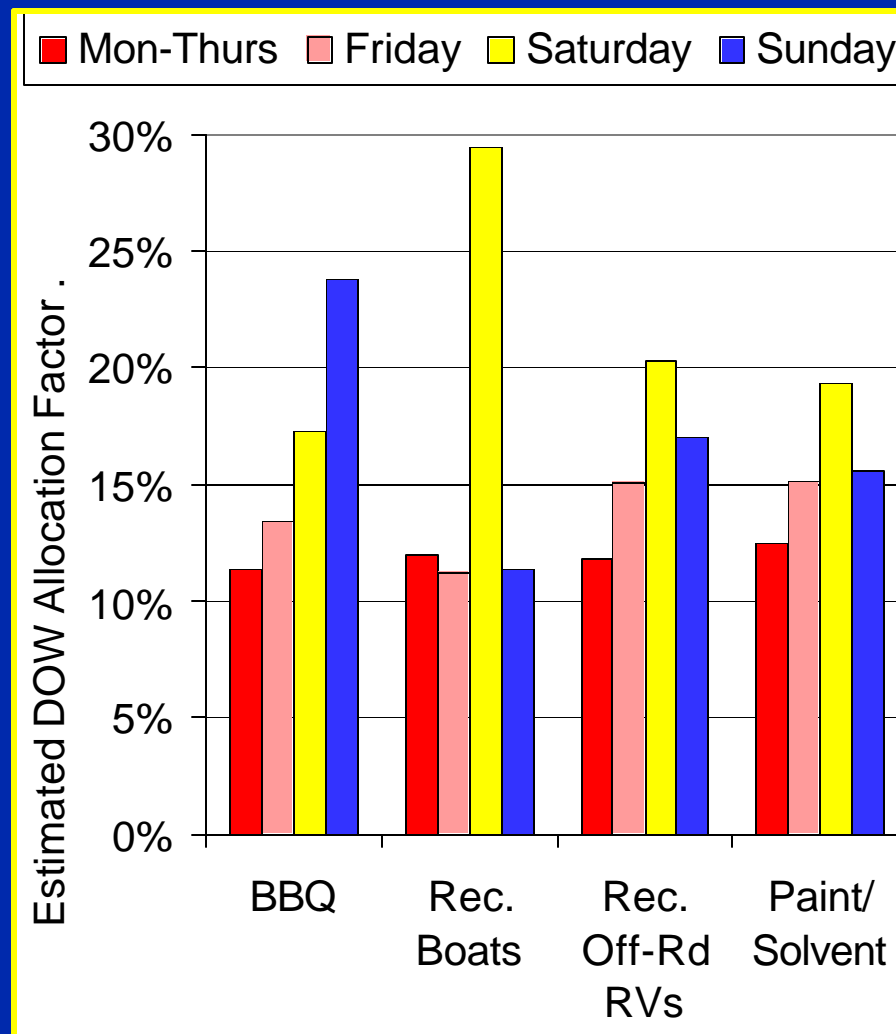
Some activities increased from WDs to WEs by 25% to 165%, including uses of

- barbecues*
- recreational boats*
- recreational off-road RVs*
- paints or solvents*

Some activities varied little by DOW, including uses of

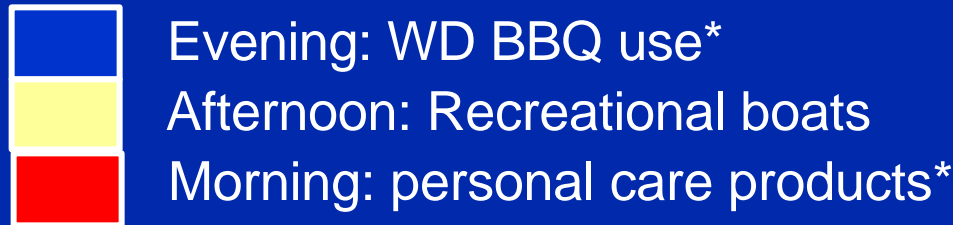
- personal care products
- water heating

*see plot



Survey Results – Household Activities

Some activities occurred at certain times of day.



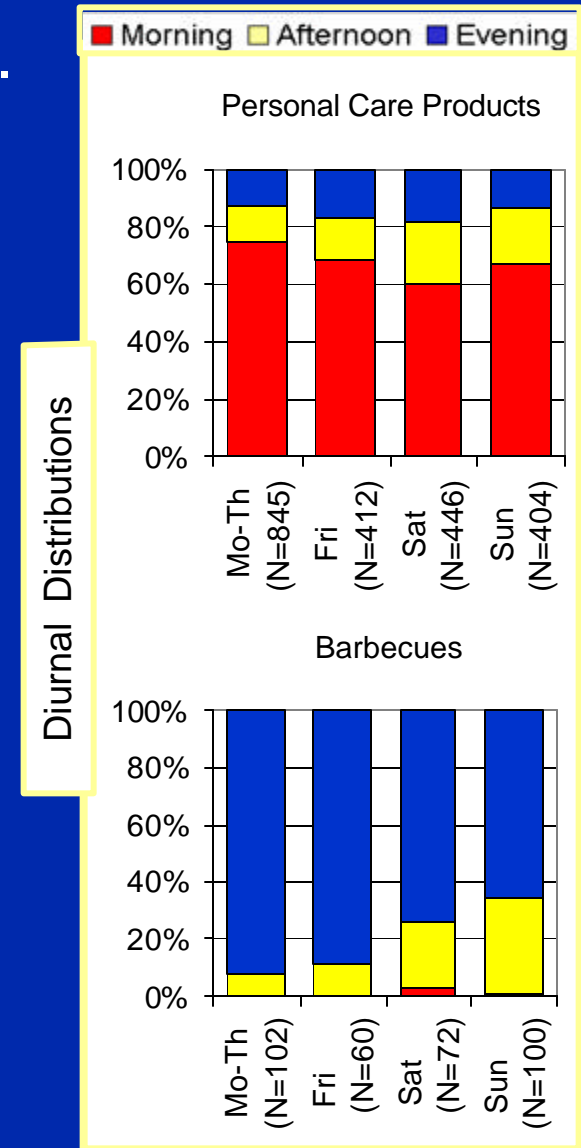
Some activities varied day-to-day.

- WD BBQ use*: 8% to 12% of total in afternoon; 90% in evening
- WE BBQ use*: 24% to 33% of total in afternoon; 66% to 74% in evening

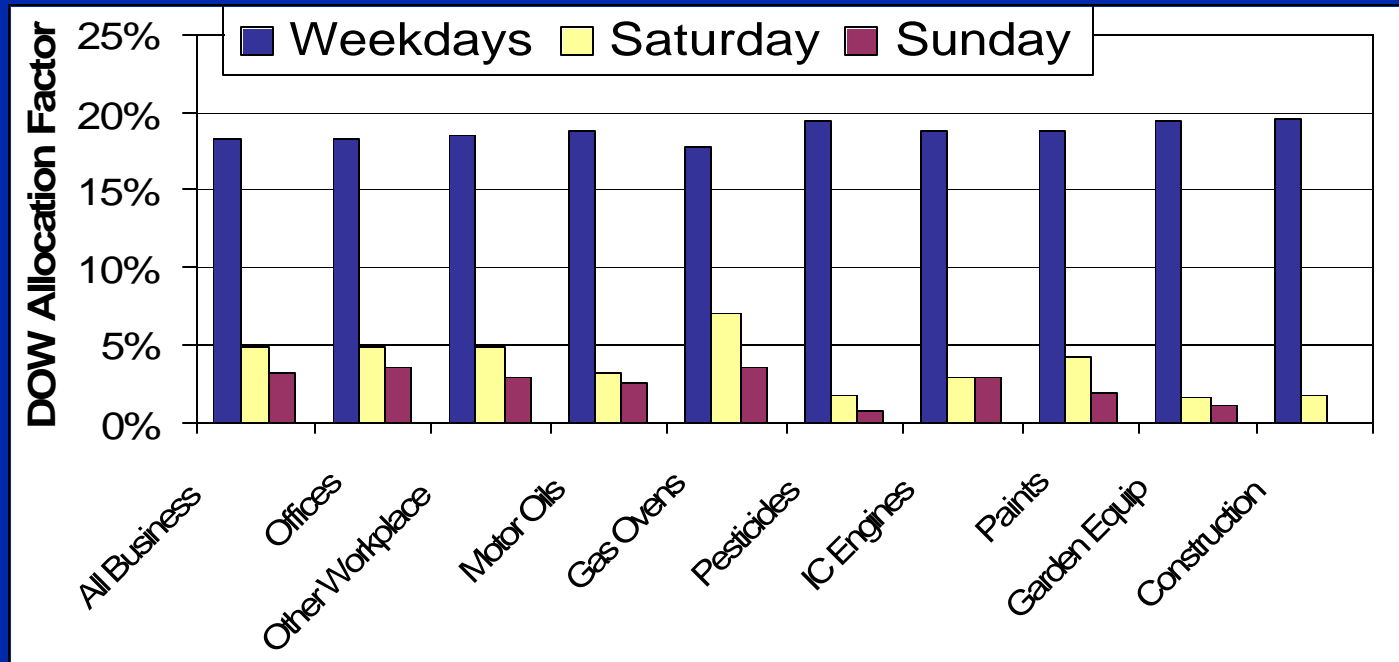
Some activities did not vary day-to-day.

- personal care products*
- water heating

*see plot



Survey Results – Household Activities



Business Type	WD-to-Sat % Reduced	WD-to-Sun % Reduced
All businesses (aggregate)	74%	82%
Gas ovens	61%	80%
Construction	90%	99%

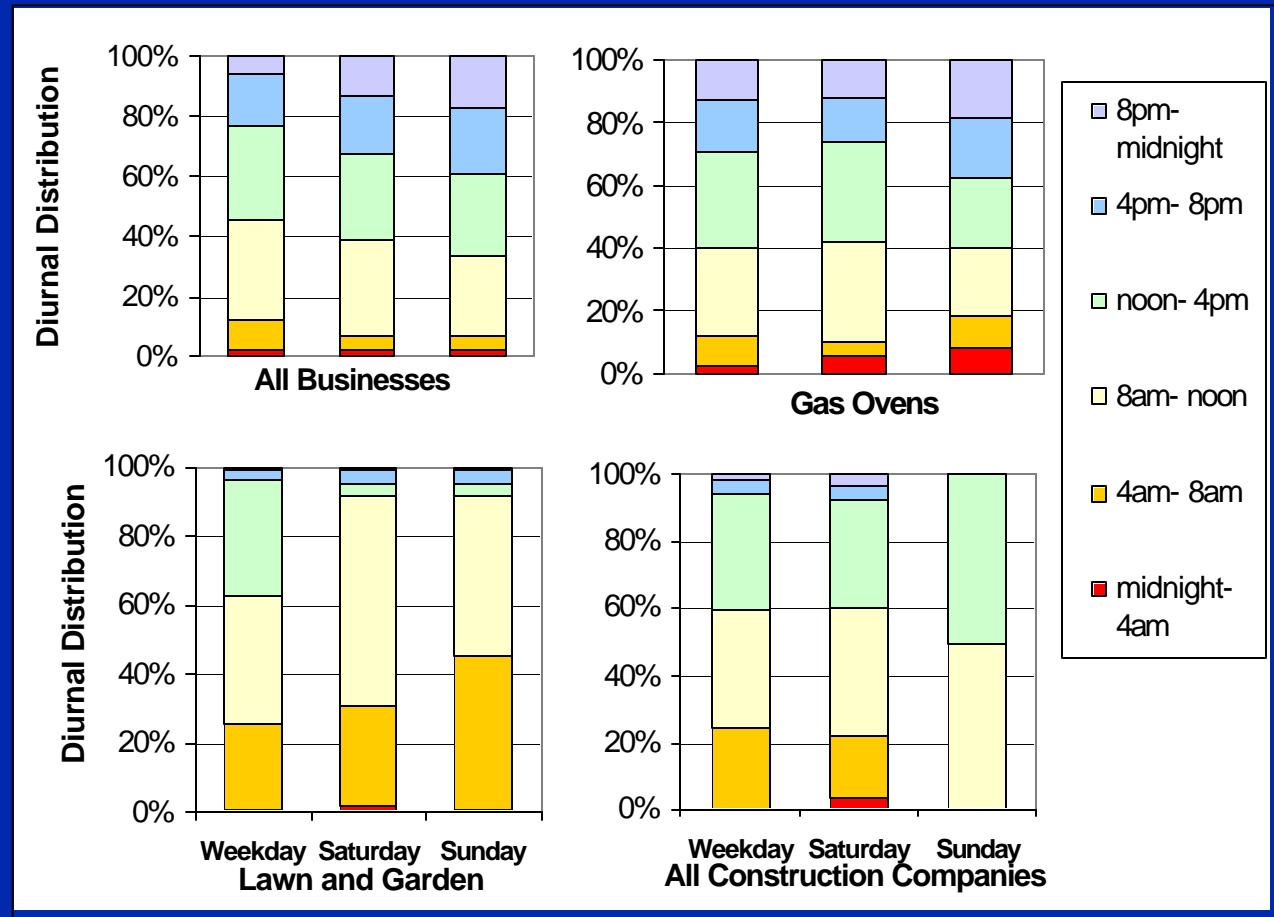
Survey Results – Household Activities

Aggregate average patterns

- On WDs, business activities peaked from 8 a.m.-4 p.m.
- On WEs, business activities were evenly distributed 8 a.m.-12 a.m.

Business type-specific patterns

- Activity with gas ovens is sustained late into the evening and late-night hours
- Activities of lawn/garden and construction businesses peak early, then drop off fast after 4 p.m.



Surveys – Findings

- Some recreational activities increased 25-165% on WDs when compared to WEs.
 - Residential use of barbecues
 - Recreational boats and off-road vehicles (note small sample sizes)
 - Use of paints or solvents
- Diurnal patterns for some residential activities varied by day of week.
 - WD use of barbecues occurs primarily in the evening, but afternoon use becomes significant on WEs.
- Other types of residential activities varied less than 25% by day of week.
 - Residential uses of personal care products
 - Water heating for showers, baths, and automatic home appliances.

Surveys – Findings

- Business activities declined by 60-99% on WEs.
- Business activity levels typically peaked from 8 a.m. to 4 p.m. on WDs and leveled out on WEs. However, exceptions existed.
 - Work at lawn/garden and construction businesses peaked from 4 a.m. to 4 p.m. on WDs and was negligible on Sundays.
 - Work at businesses with gas ovens peaked later in the day on WDs and sustained through the evening and on WEs.

Instrumented Vehicle Study



Instrumented Vehicle Study Participation

- A subset of household survey participants was recruited.
 - 68 households
 - 107 vehicles
- Global positioning system (GPS) receivers with data loggers—GeoLoggers—were installed in all household vehicles.
- Time-activity data were recorded at 5-second intervals for 10 to 15 days.
 - Vehicle position
 - Vehicle speed
- Approximately 1200 vehicle-days of data were collected.

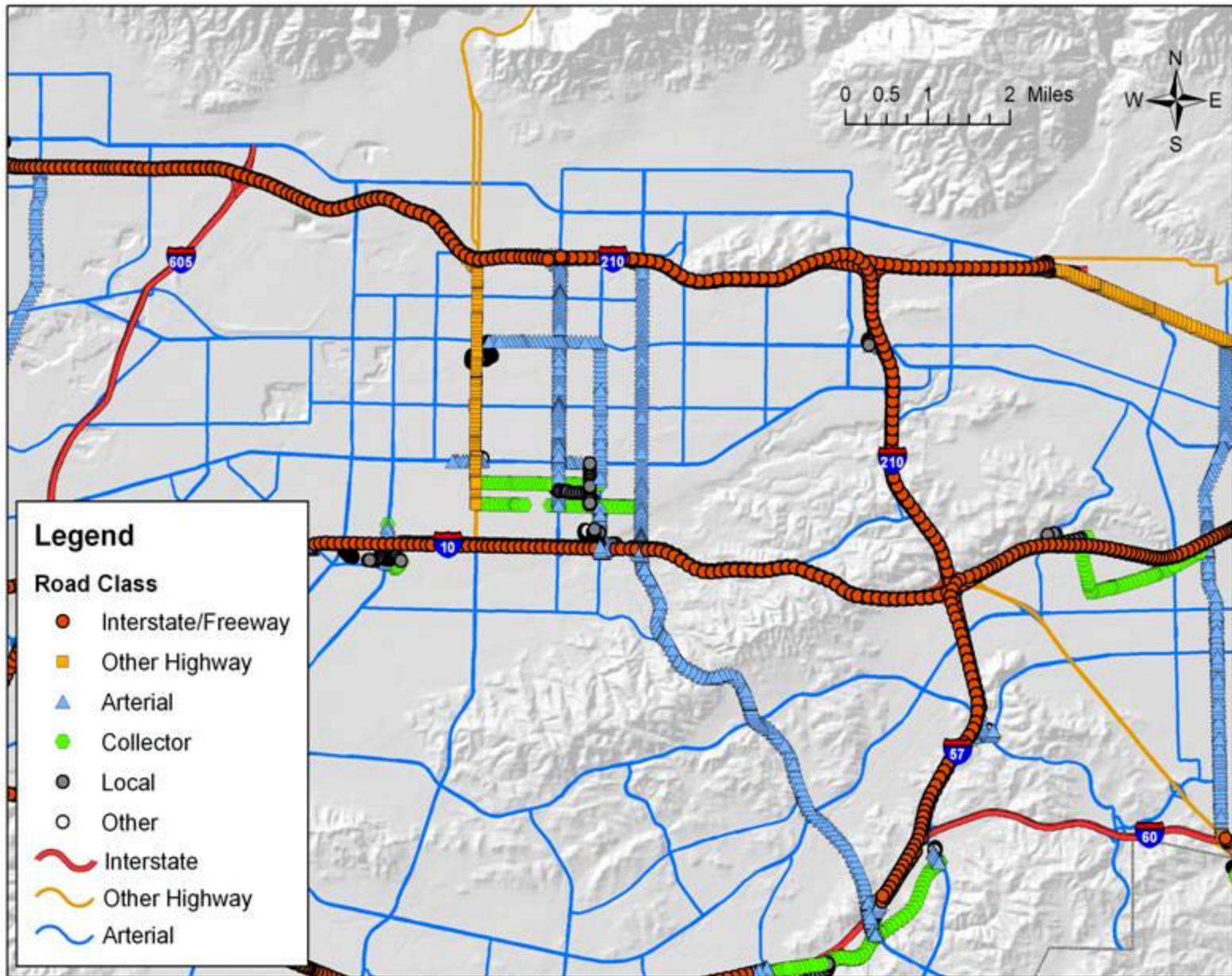
GeoLogger



GeoLogger Study Participation

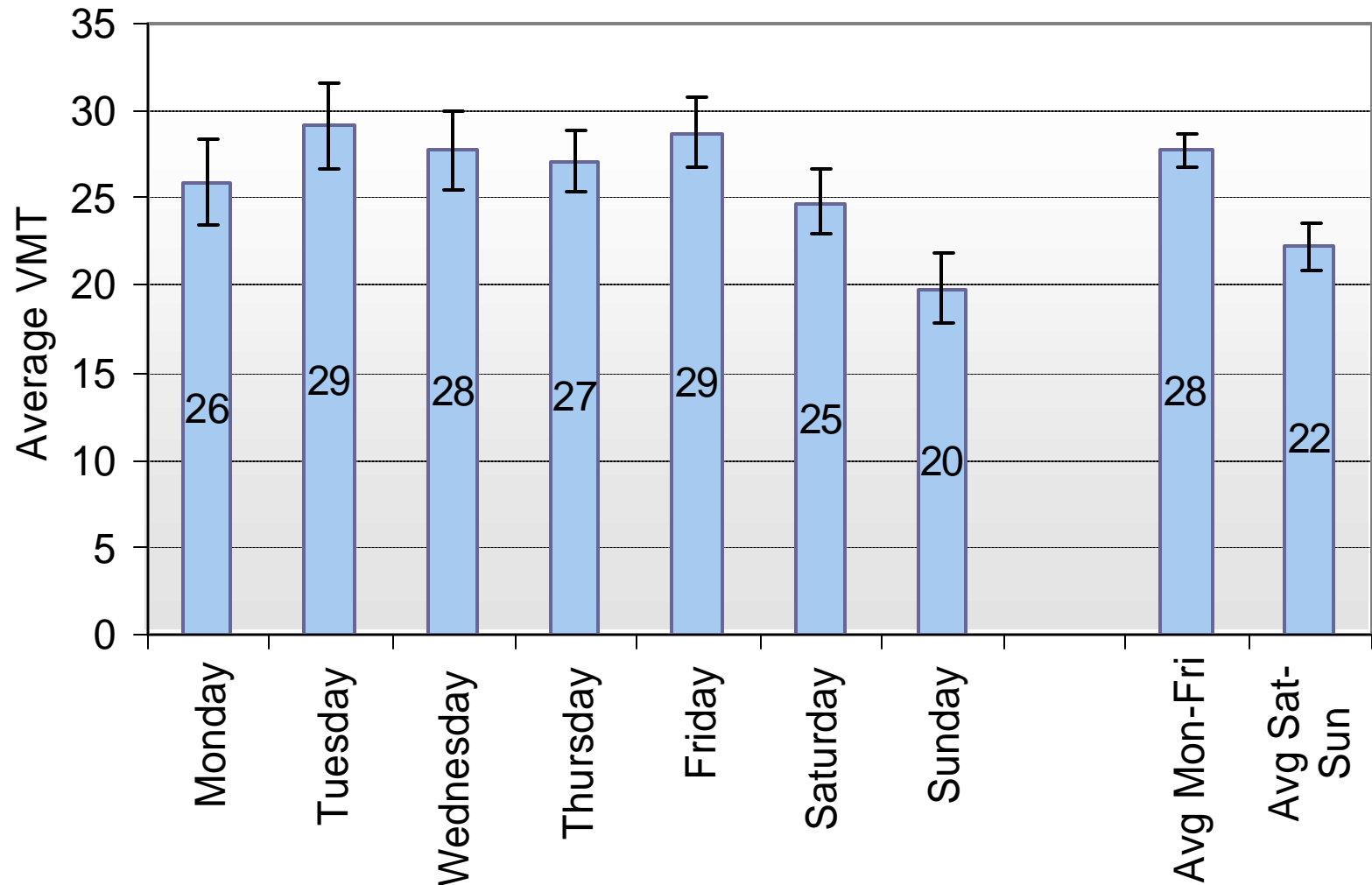


GeoLogger Study – Example Data



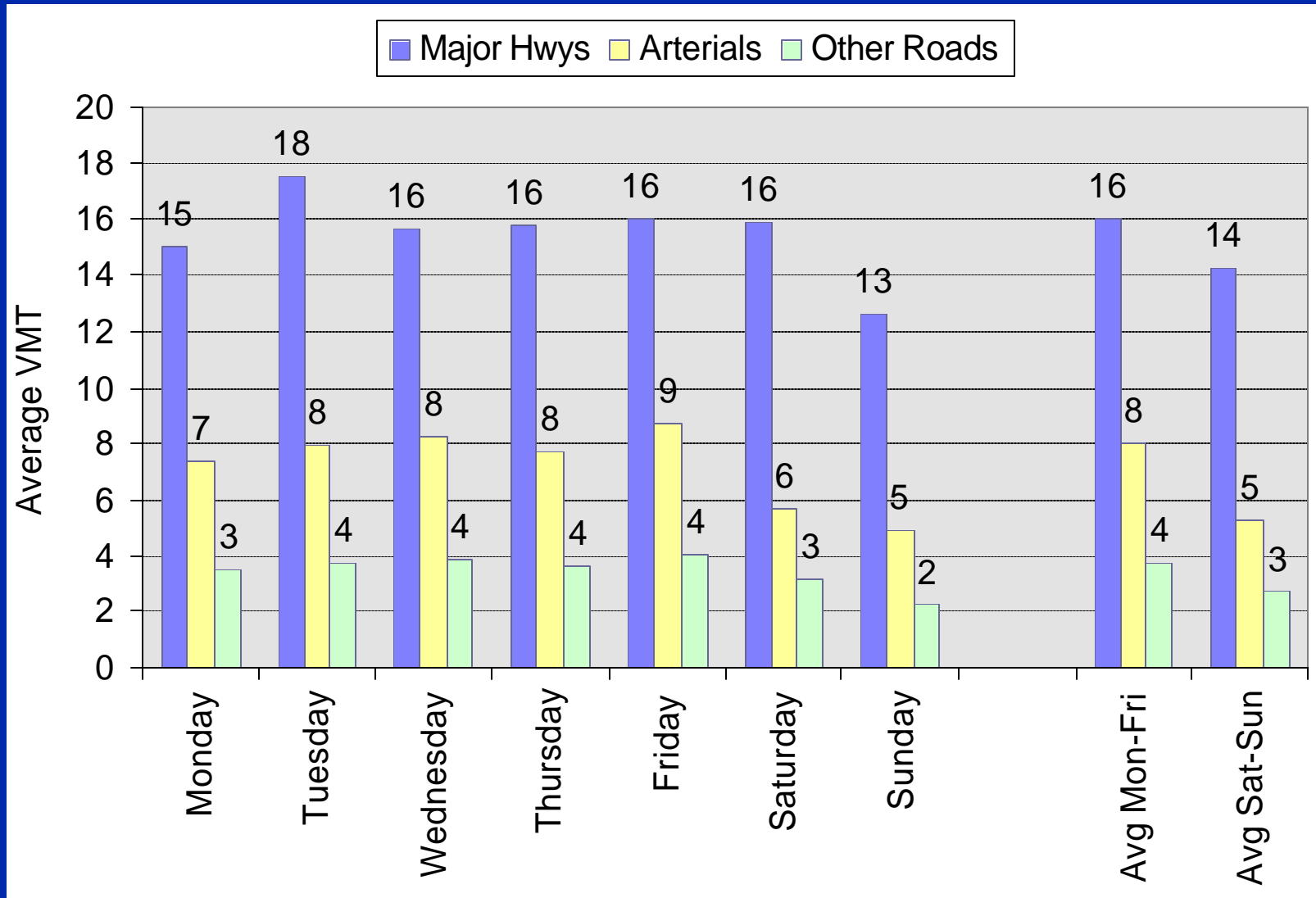
GeoLogger Study – Results

Average Daily VMT per Vehicle



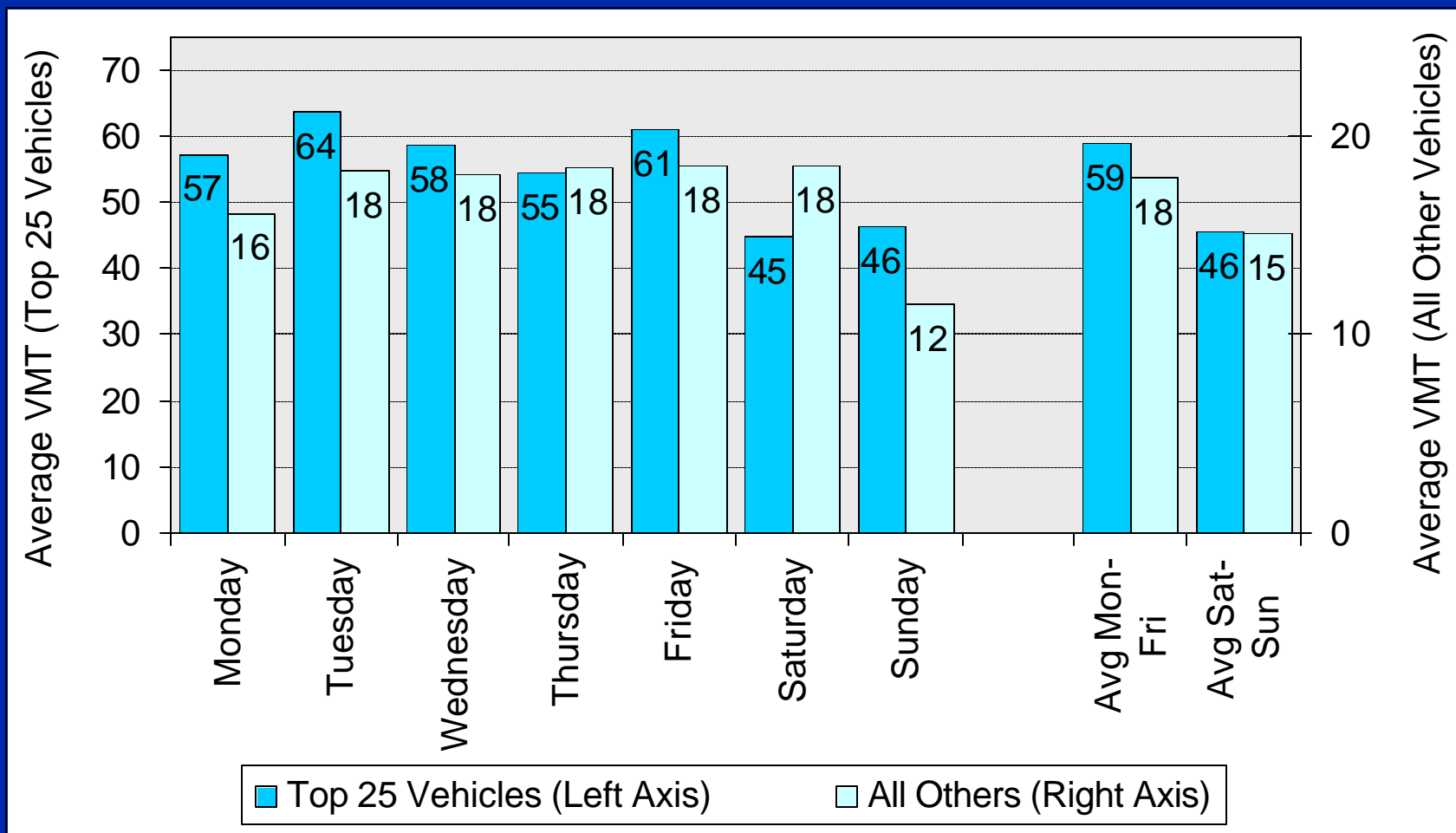
GeoLogger Study – Results

Average Daily VMT per Vehicle by Road Type



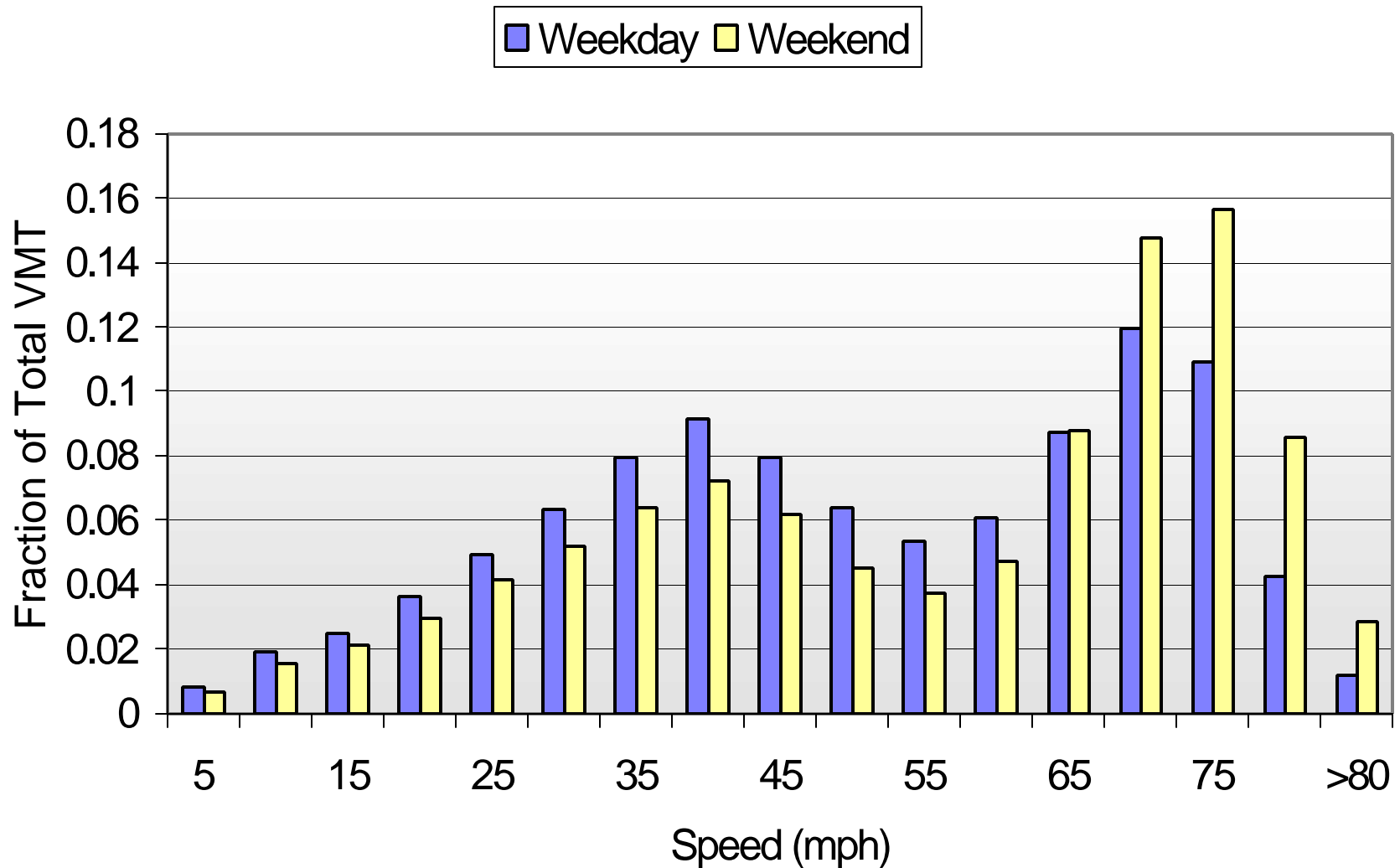
GeoLogger Study – Results

Driving patterns for high-mileage vehicles (“top 25”) differed somewhat from those of other vehicles.



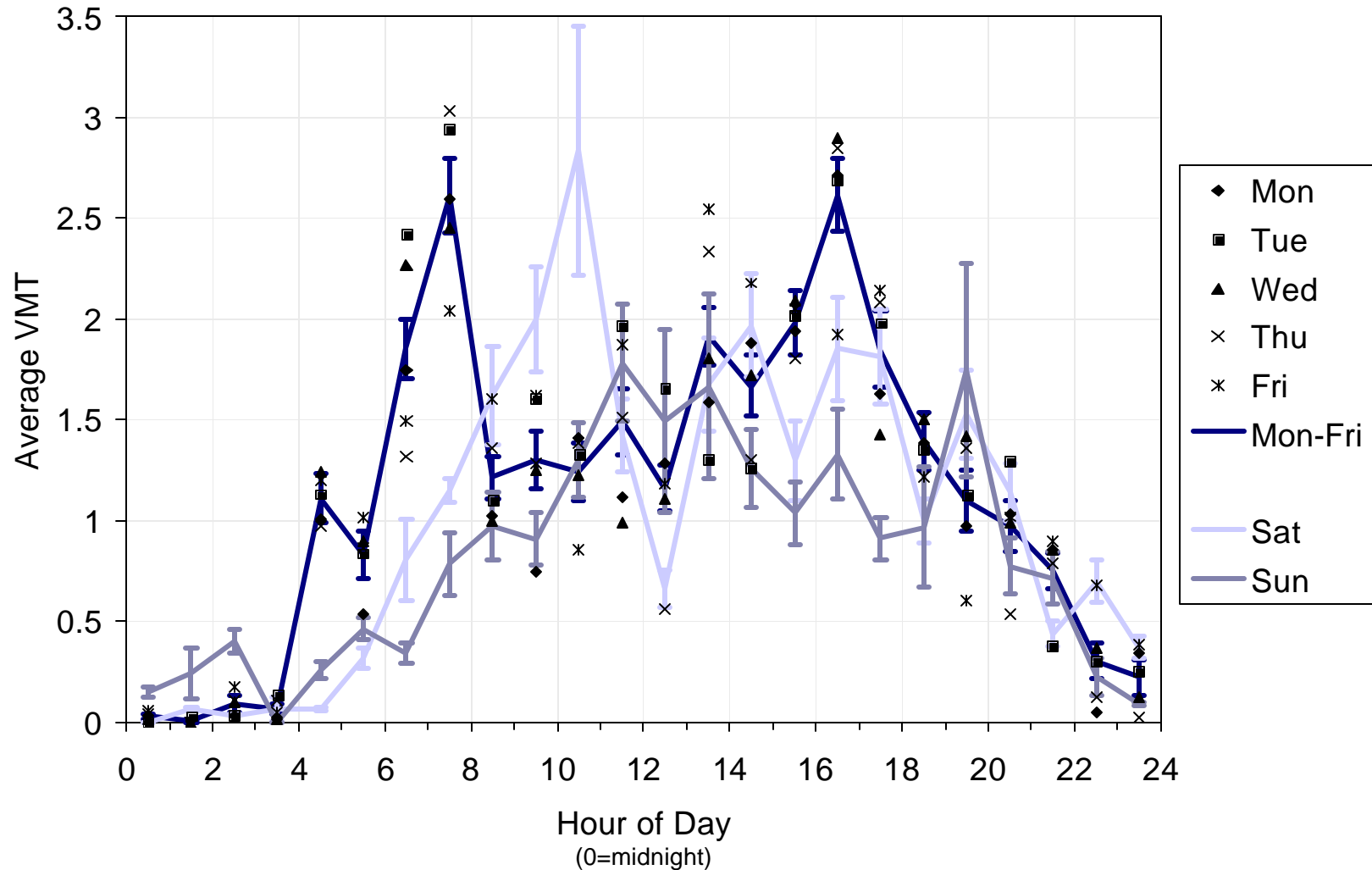
GeoLogger Study – Results

WD-WE VMT by Speed Distribution



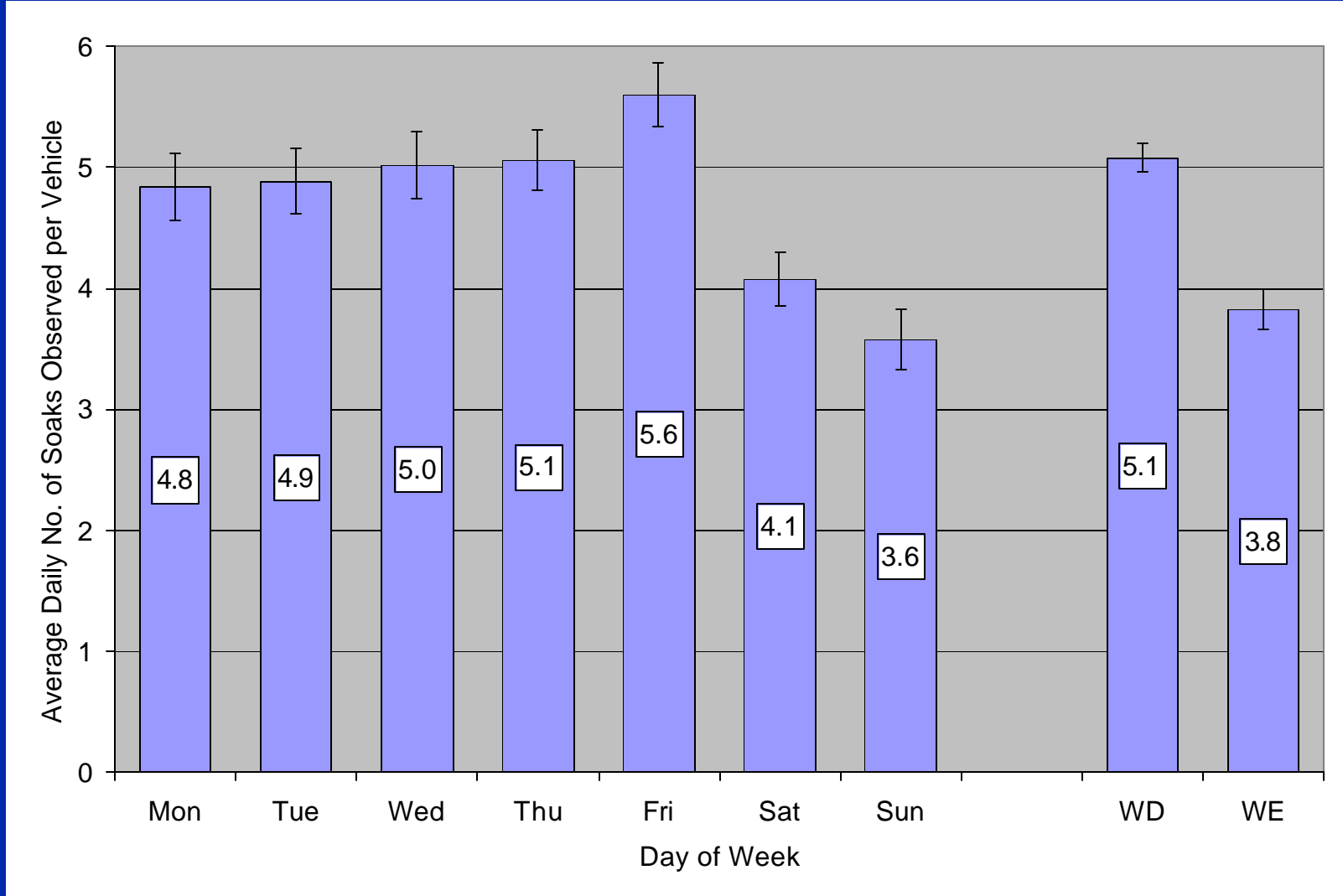
GeoLogger Study – Results

Average Hourly VMT per Vehicle



GeoLogger Study – Results

Average Daily No. of Soaks per Vehicle



GeoLogger Study – Findings

- Accruals of VMT at high speeds were observed.

Time Period	Proportion of VMT Accrued Above 65 mph
Monday-Friday	28%
Saturday-Sunday	42%
Monday-Friday, 7 a.m.-9 a.m.	28%
Monday-Friday, 4 p.m.-7 p.m.	28%

GeoLogger Study – Findings

- Weekly patterns of VMT were observed.

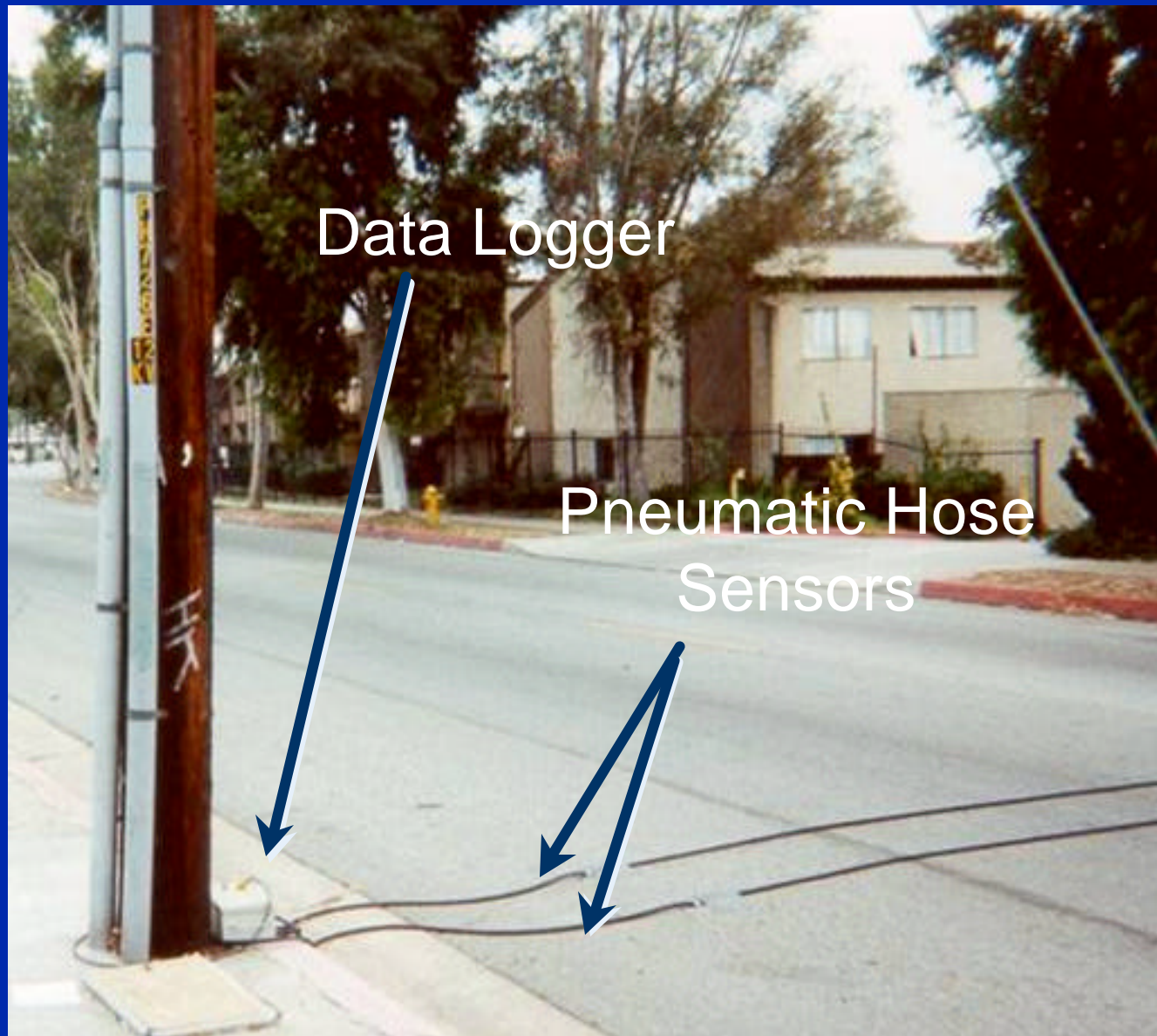
Day of Week	Average VMT	Change (Relative to Mon-Thurs)	Percent Change
Friday	29	Increase	0-4%
Saturday	25	Decrease	0-24%
Sunday	20	Decrease	22-33%

GeoLogger Study – Findings

- Patterns in the frequencies of trips were observed.

Day of Week	Average No. of Trips
Monday-Thursday	4.8 to 5.1
Friday	5.6
Saturday	4.1
Sunday	3.5

Surface Street Traffic Counters

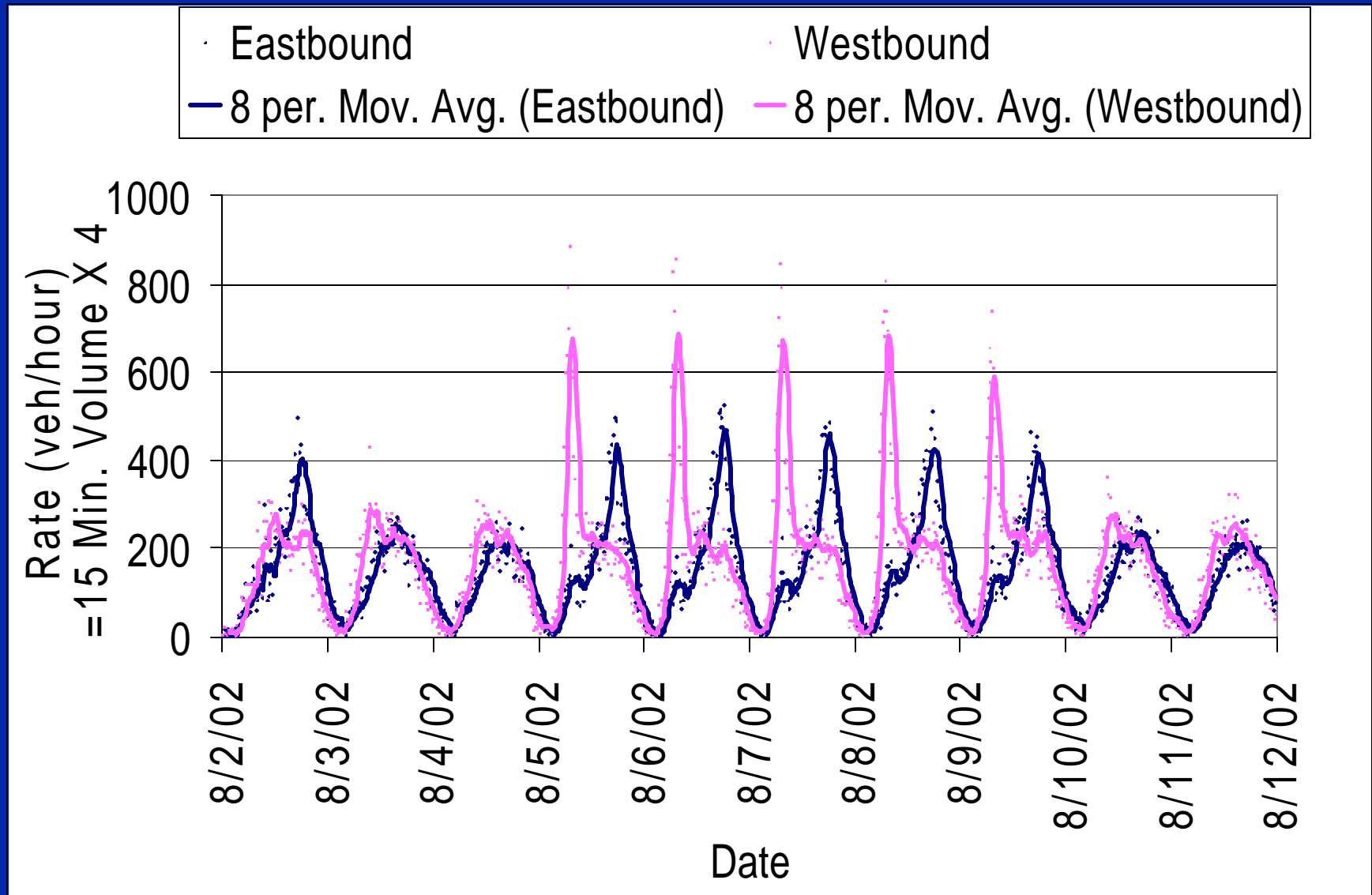


Surface Street Traffic Counters

- Counters were deployed at 30 sites for 10-day periods.

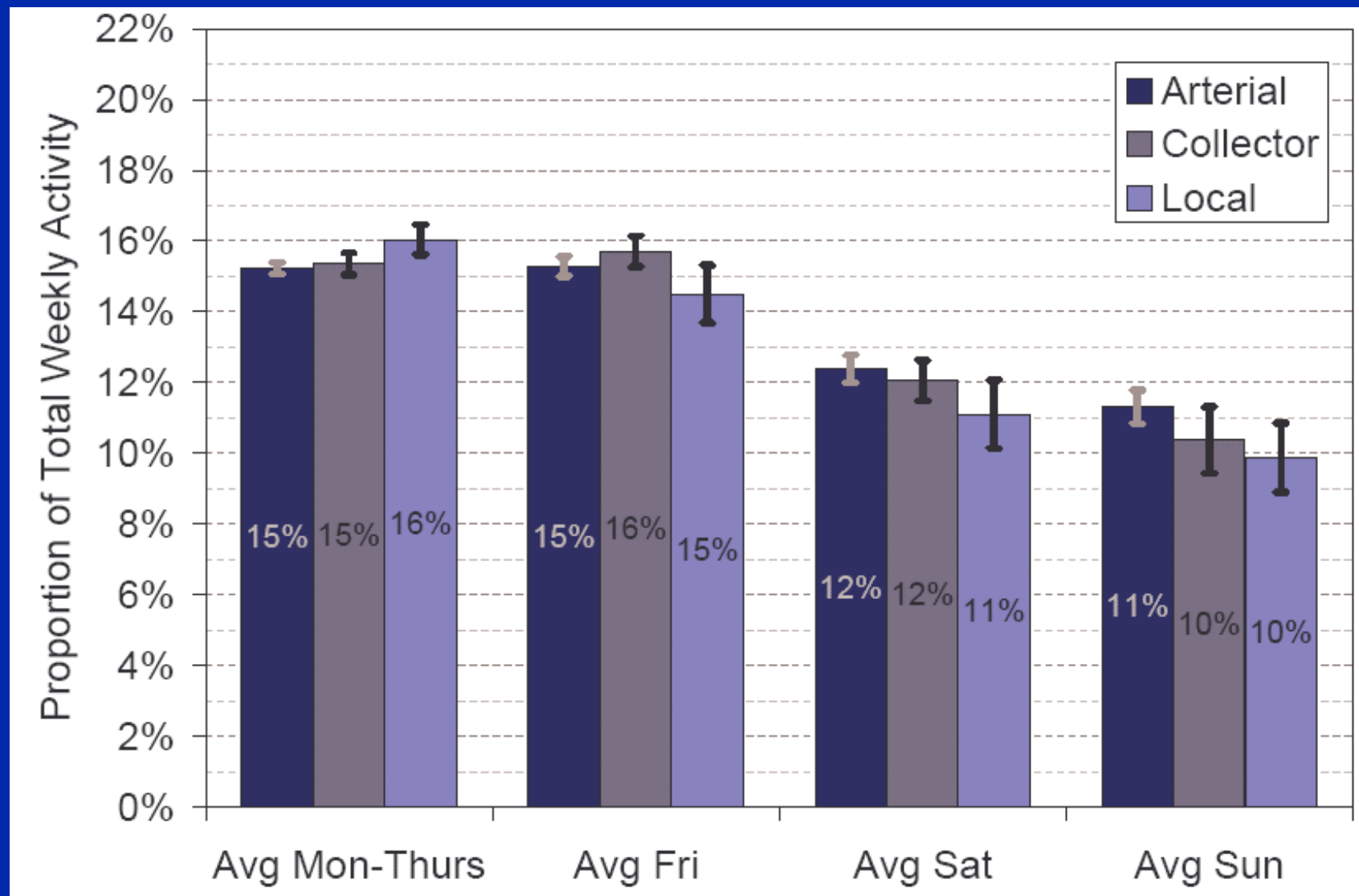


Surface Street Traffic Counters – Example Data



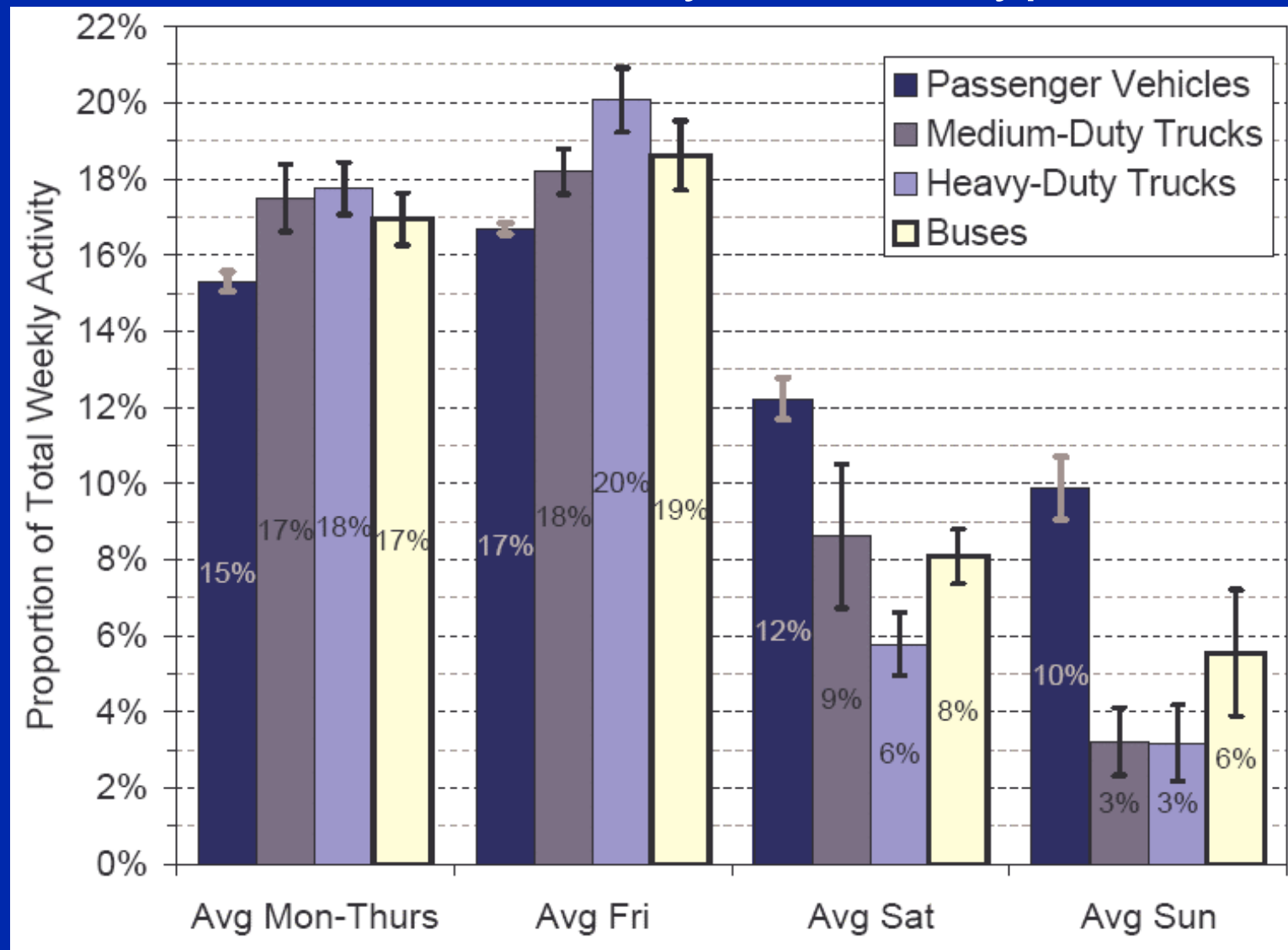
Surface Street Traffic Counters – Results

Traffic Volumes by Road Type



Surface Street Traffic Counters – Results

Traffic Volumes by Vehicle Type



Surface Street Traffic Counters – Findings

- Diurnal patterns of VMT were observed.

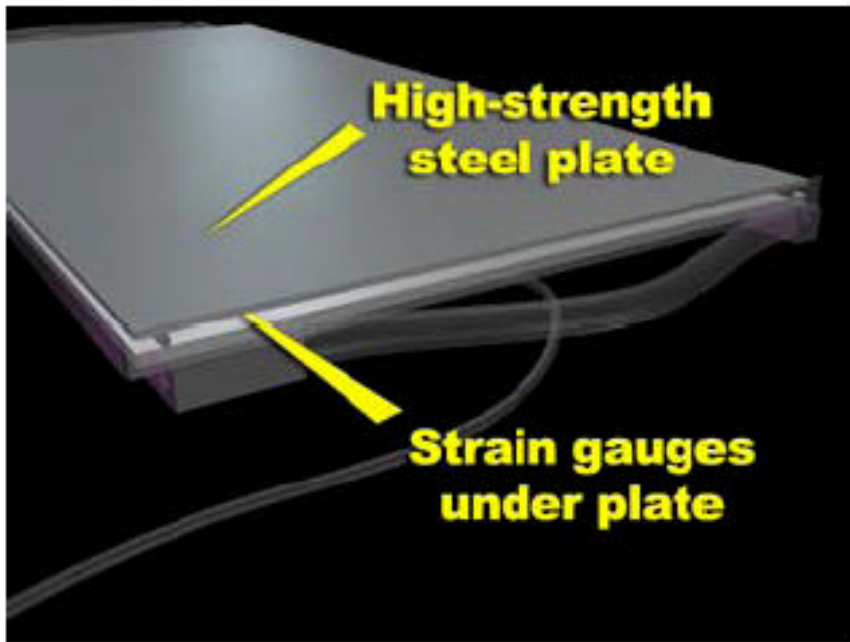
Day of Week	Peak Pattern	Times of Peak
Monday-Friday	Sharp	7 a.m.-8 a.m. 4 p.m.-5 p.m.
Saturday-Sunday	Gradual	Noon-5 p.m.

Surface Street Traffic Counters – Findings

- Patterns in traffic volumes were observed.

Vehicle Type	Day of Week	Change (Relative to Mon-Thurs)	Percent Change
Light duty	Saturday	Decrease	25%
	Sunday	Decrease	33%
Heavy duty	Saturday	Decrease	56%
	Sunday	Decrease	83%

Caltrans WIM Data



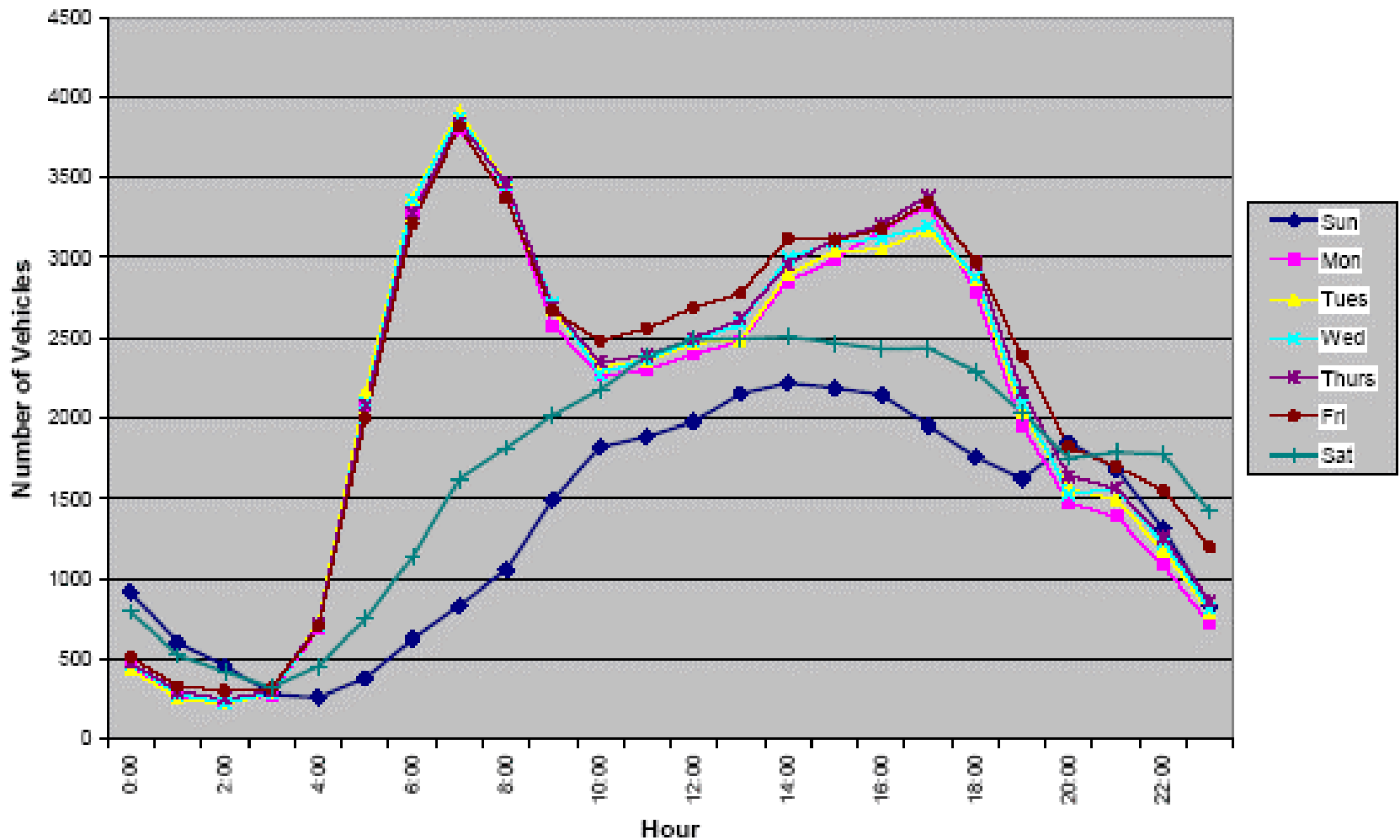
Source of Photos: Oak Ridge National Laboratory

Acquisition of WIM Data



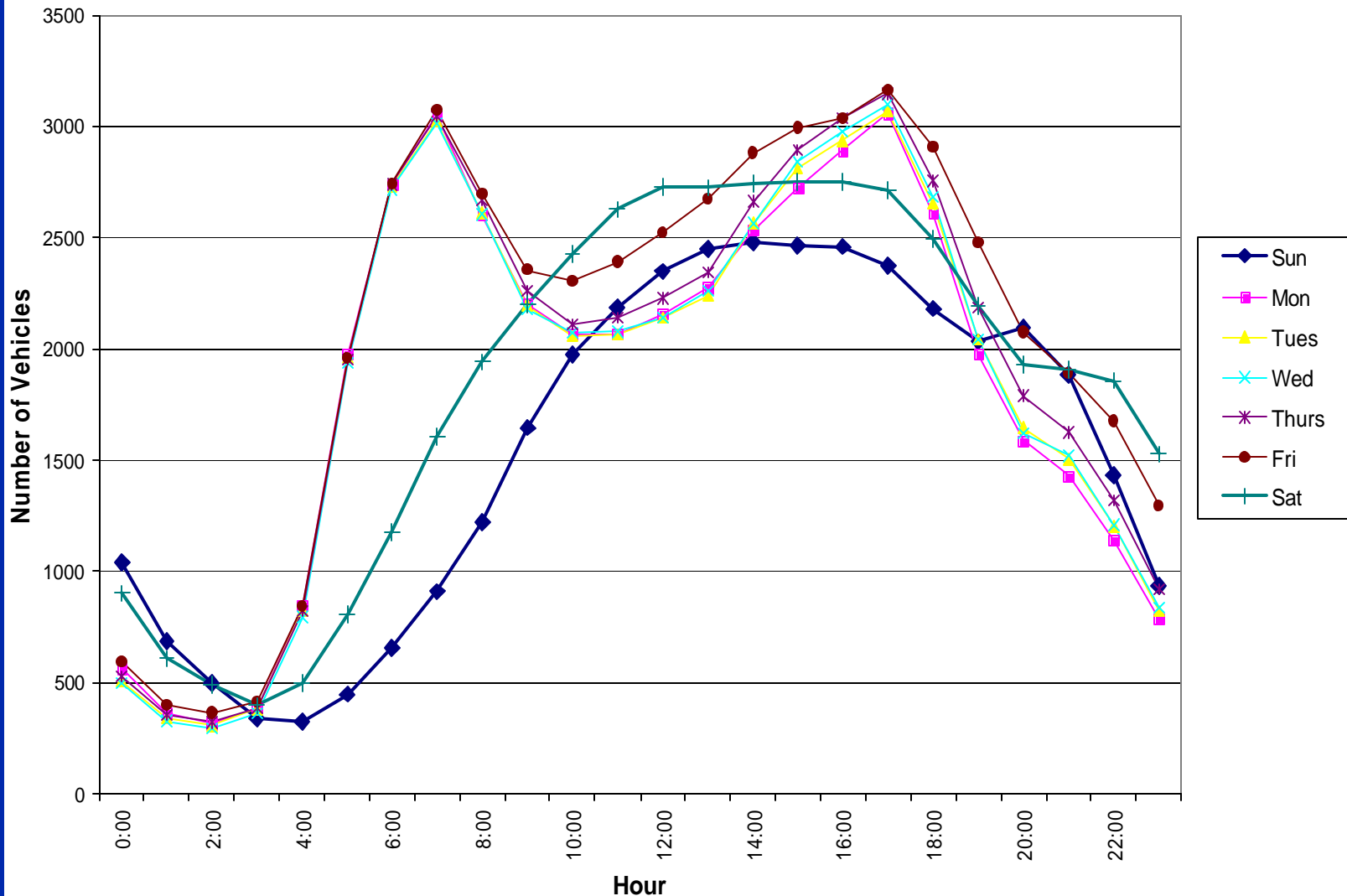
Example WIM Data

WIM Site Artesia: Passenger/2-3 axle Vehicles



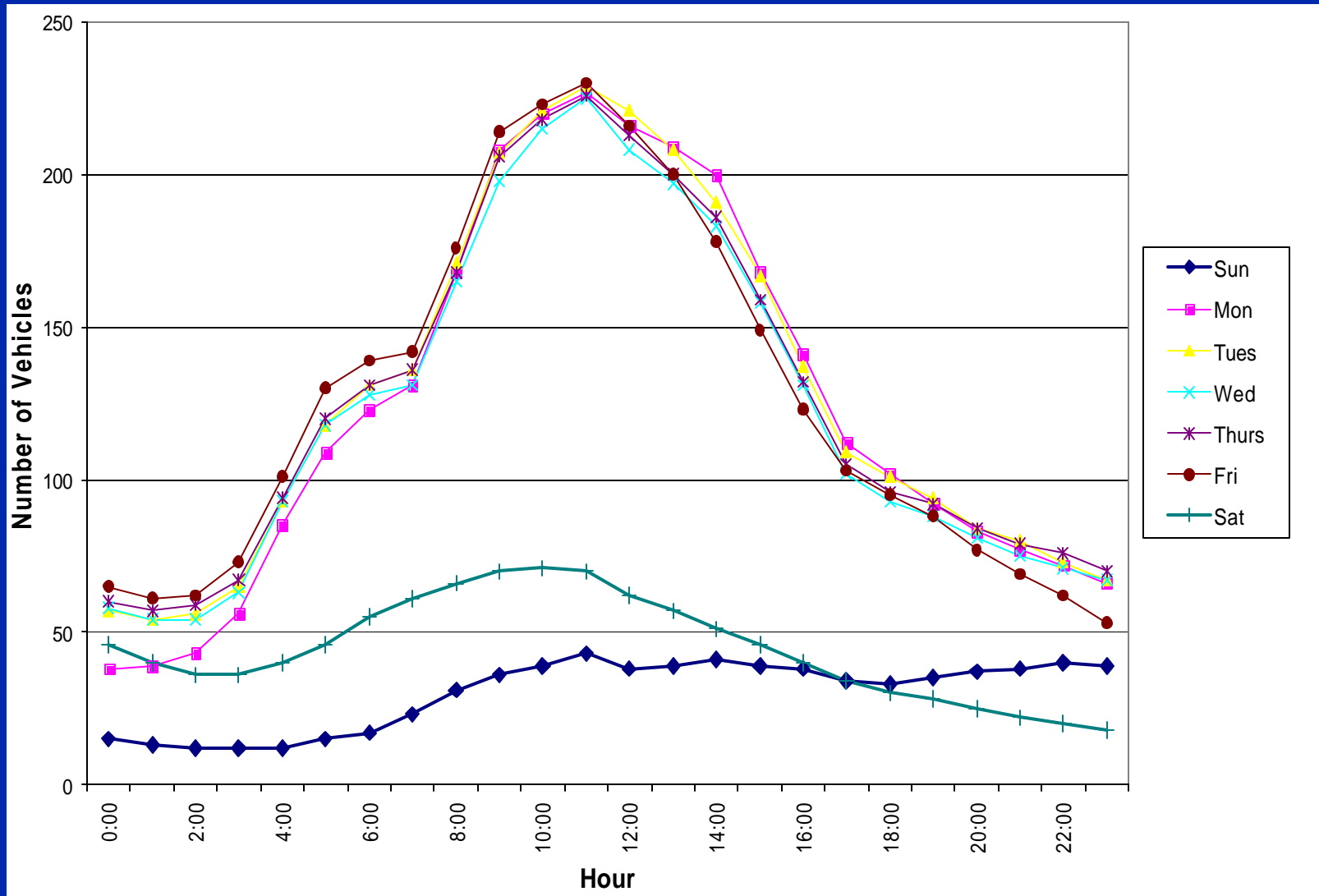
WIM Data Analyses – Results

Average Diurnal Traffic Volumes: Light-Duty Vehicles



WIM Data Analyses – Results

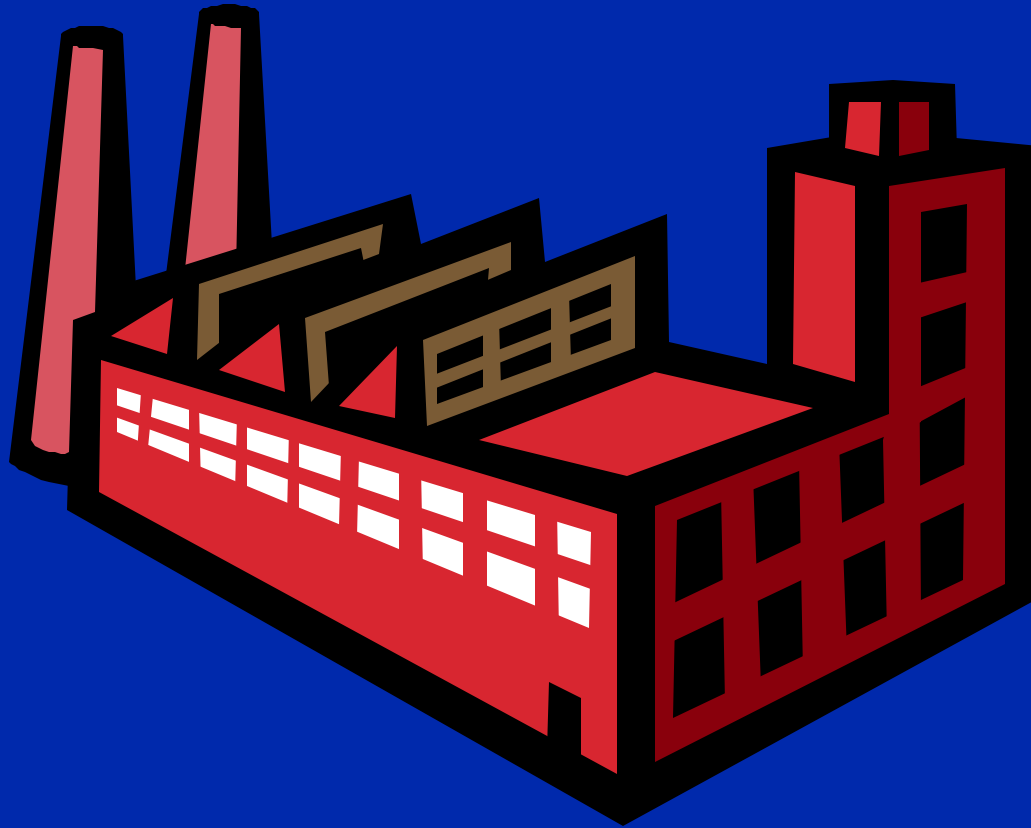
Average Diurnal Traffic Volumes: Heavy-Duty Vehicles



WIM Data Analyses – Findings

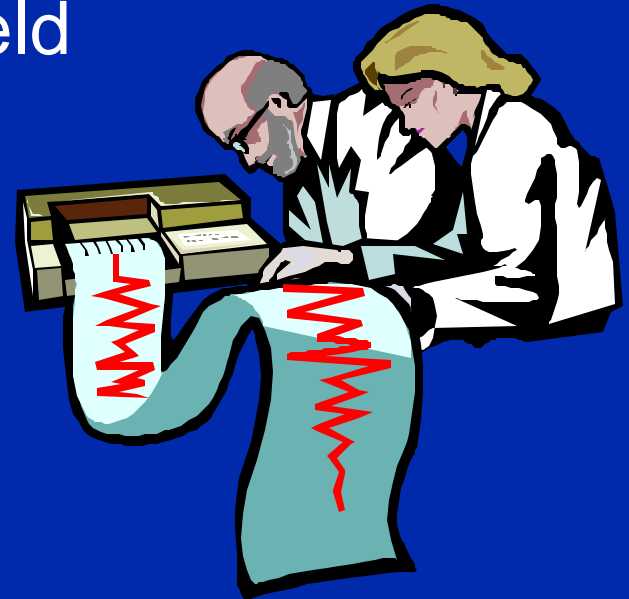
Vehicle Type	Day of Week	Diurnal Pattern	Percent Change
Light duty	Weekday	Bimodal	<i>n/a</i>
	Weekend	Single mode	Decrease 11-26%
Heavy duty	Weekday	Single mode	<i>n/a</i>
	Weekend	Single mode	Decrease 50-75%

CEMS Data

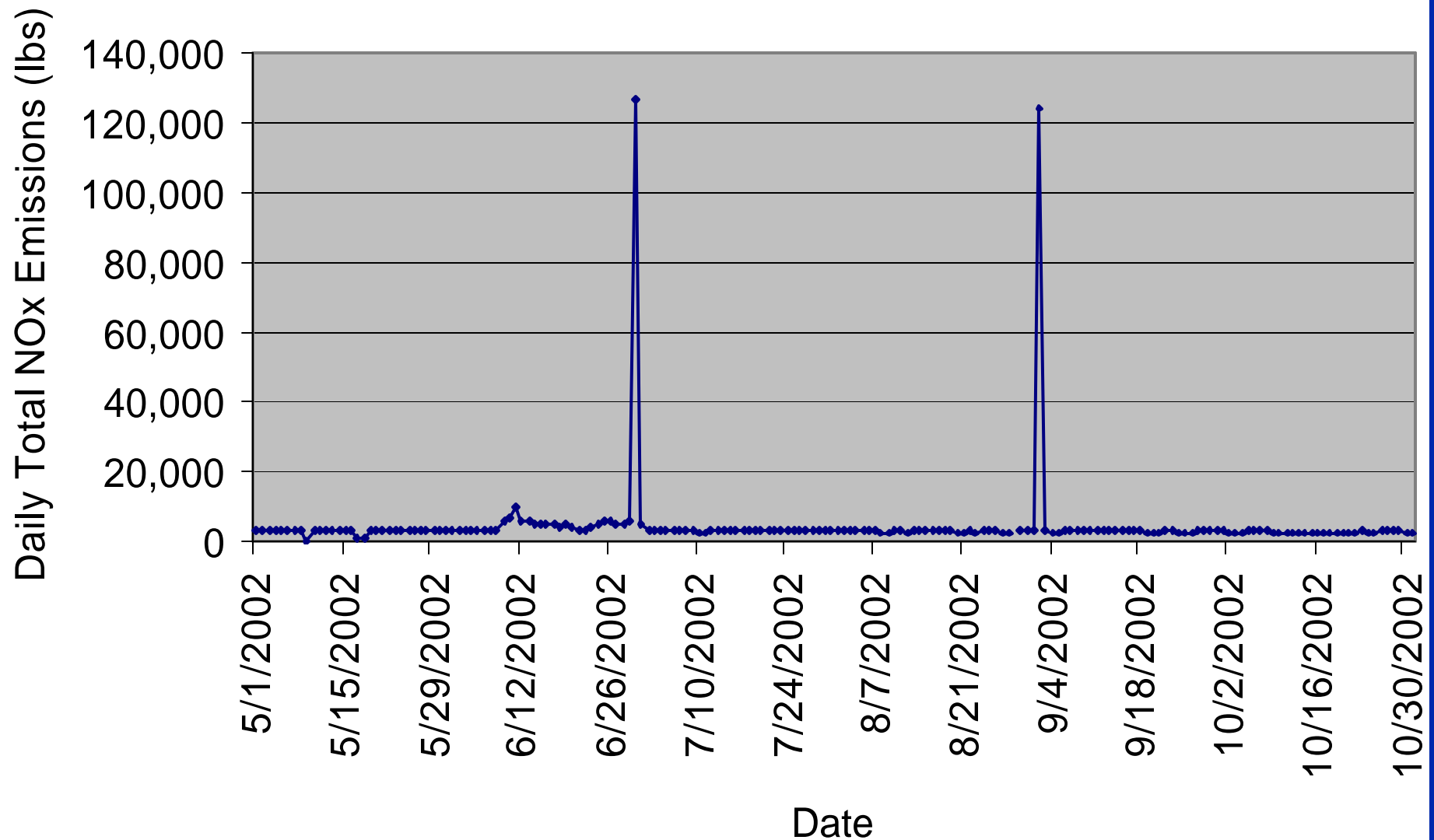


Acquisition of CEMS Data

- CEMS data were provided by the South Coast Air Quality Management District.
 - SoCAB major point sources
 - May 2002 through October 2002
 - Daily total NO_x
 - Confidential information withheld

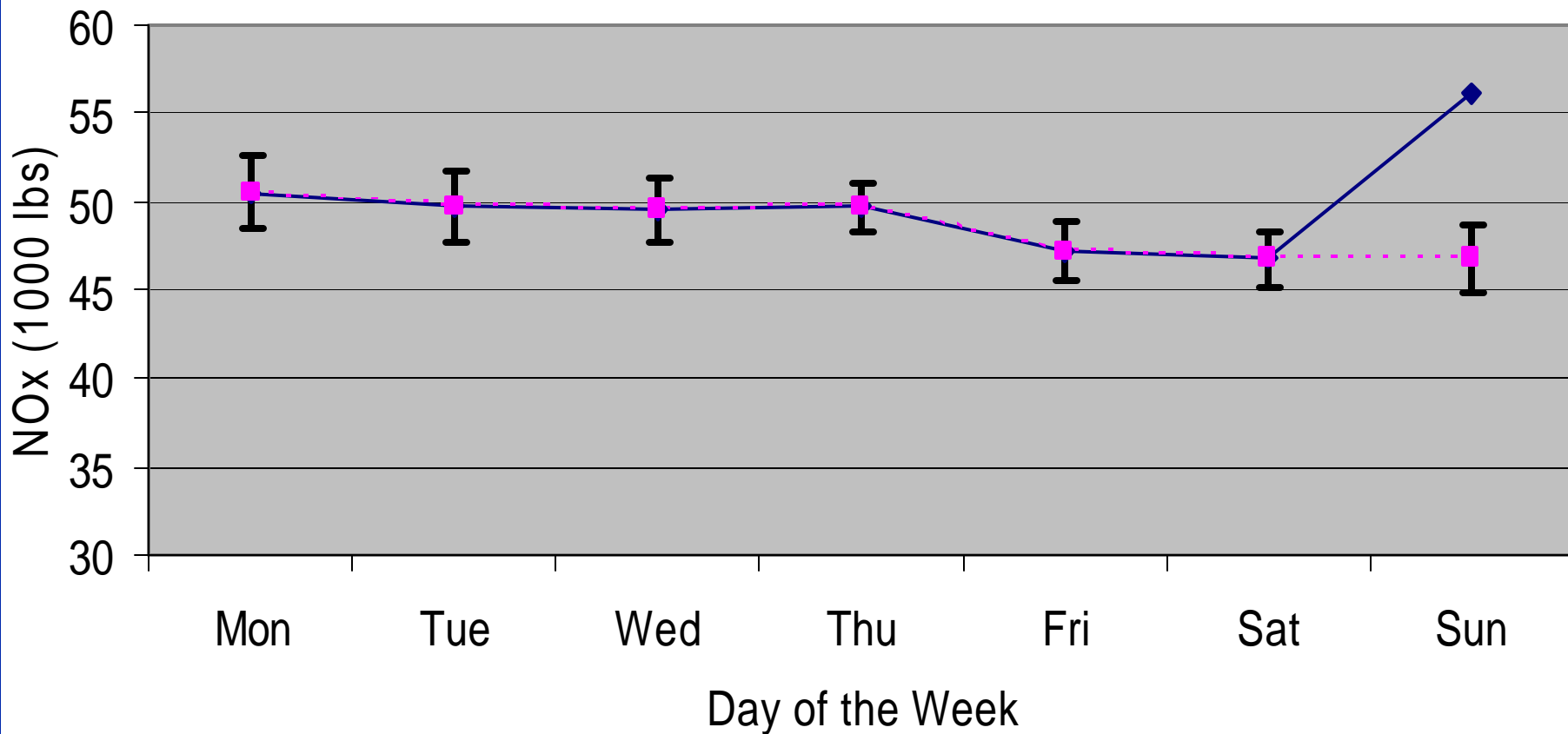


Example CEMS Data



CEMS Data Analyses – Results

Error bars represent ± 1 standard error of the mean



—◆— Original Data - - - ■ - - - With June 30 Normalized

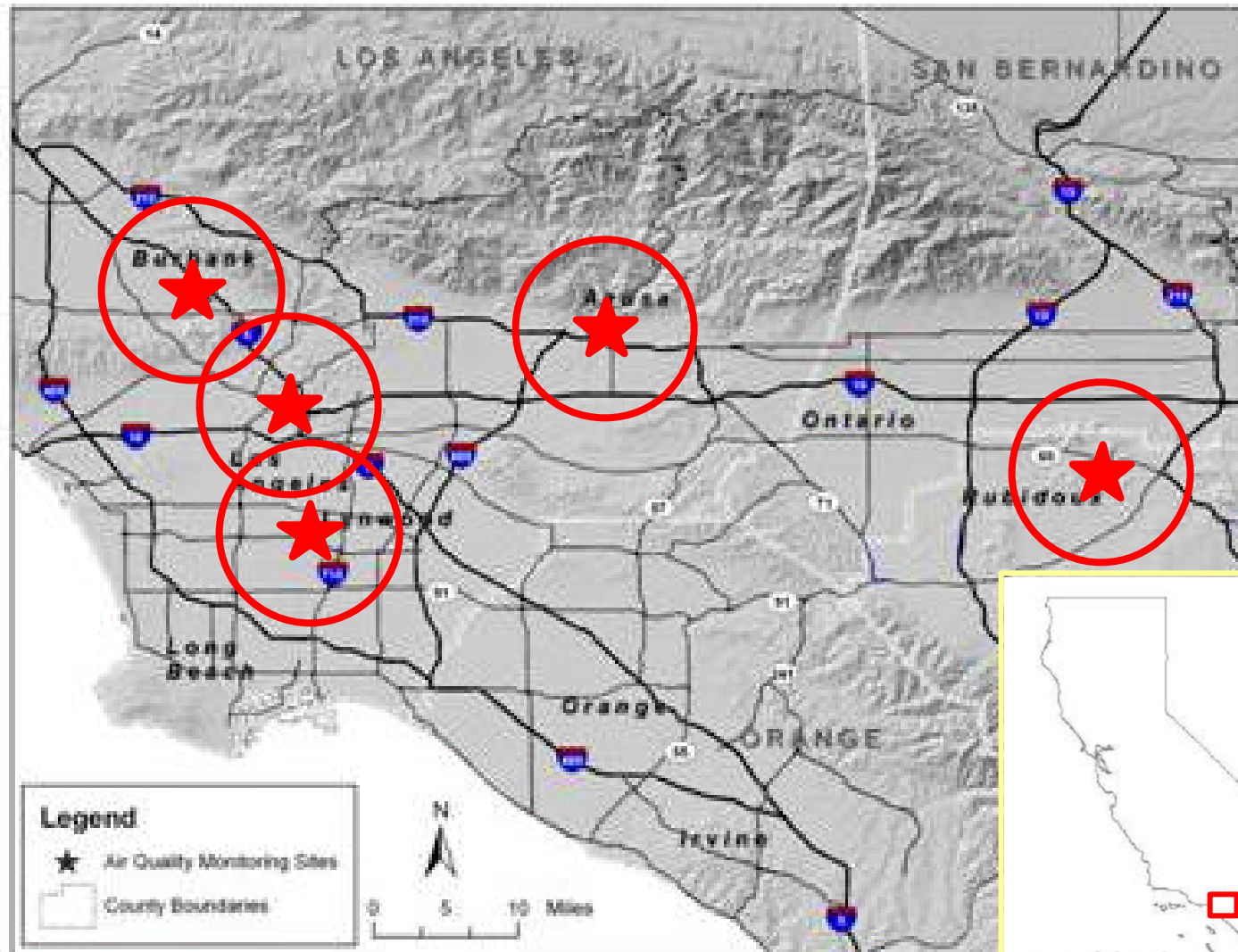
CEMS Data Analyses – Results

Time of Week	NO _x Emissions (1000 lbs)		
	Largest 20 Emissions Sources	Other 58 Emissions Sources	Total
Average WD (Mon-Thu)	40.23	9.67	49.90
Average Friday	37.92	9.26	47.18
Average WE (Sat-Sun)	38.17	8.58	46.75
% Decrease WD to WE	5.11%	11.25%	6.30%

CEMS Data Analyses – Findings

- NO_x emissions from major point sources declined 6% on Friday-Sunday (relative to Monday-Thursday).
- Low-emitting facilities experienced larger WD-WE variability than high-emitting facilities.
- Emissions from high-emitting facilities declined Friday-Sunday.
- Emissions from low-emitting facilities declined only on Saturday and Sunday.

Special Studies in Neighborhoods



55

- 55

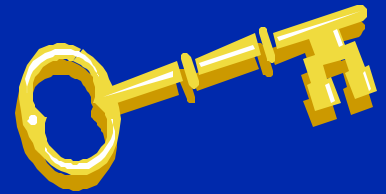


Summary and Wrap-Up

- Key Findings
- Recommendations for Modeling
- Recommendations for Further Research
- Closing Remarks
- Acknowledgments



Key Findings



- Activity levels for on-road mobile and business-related sources decline on WEs relative to WDs.
- Activity levels for recreation-related sources increase on WEs relative to WDs.
- NO_x emissions from major point sources decline on WEs.
- Substantial accrual of VMT occurs at vehicle speeds above 65 miles per hour, especially on WEs.
- Travel predominantly occurs on major highways, especially on WEs.

Recommendations for Modeling

Variable	Average Value, Monday- Thursday	Units
Light-duty VMT	28	Miles per vehicle-day
Light-duty soaks or trips	5	Soaks per vehicle-day

Recommendations for Modeling

Variable	Day of Week	Change	Percent Change
Light-duty VMT	Friday	Increase	3.5%
	Saturday	Decrease	10-20%
	Sunday	Decrease	30%
Light-duty soaks or trips	Friday	Increase	10%
	Saturday	Decrease	20%
	Sunday	Decrease	30%

Recommendations for Modeling

Variable	Day of Week	Change	Percent Change
Heavy-duty VMT	Saturday	Decrease	55-70%
	Sunday	Decrease	75-80%
Activity levels for recreational sources	Saturday or Sunday	Increase	25-165%, depending on the source category
Activity levels for commercial sources	Saturday or Sunday	Decrease	60-99%, depending on the source category

Recommendations for Modeling

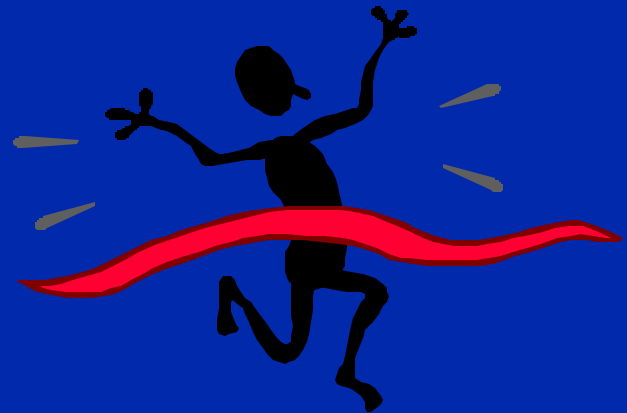
- Apply changes to activity patterns for light-duty vehicles.
 - Apply a single-mode diurnal profile to represent WE activity patterns.
 - Slightly increase the proportion of VMT occurring on Friday afternoons and evenings.
 - Adjust speed distributions to reflect high proportions of VMT occurring at high speeds.
- Apply diurnal profiles to recreational emissions sources favoring activities in the afternoons.
- Apply day-specific emissions data for NO_x from point sources.

Recommendations for Further Research

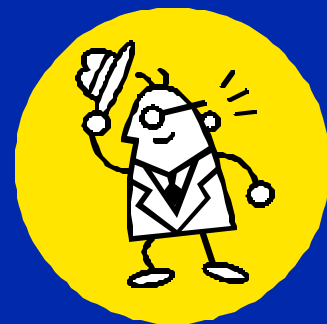
- Continue to mine the databases generated through this project.
- Develop emission factors for on-road vehicles that correspond to high speeds above 65 mph.
- Investigate further whether the modeled number of starts and/or soaks per day should be reduced.
- Investigate further the extent to which emissions should be spatially re-allocated on WEs.
- Investigate further the differences in activity patterns for light-duty utility vehicles and passenger vehicles.

Closing Remarks

- Significant WD-to-WE variability occurs across all components of the emission inventory: point, area, and mobile.
- Much of this variability can now be quantified for the SoCAB.



Acknowledgments



- Leon Dolislager of the California Air Resources Board (ARB) was the ARB technical contact and Project Officer.
- Population Research Systems of San Francisco conducted surveys and recruited study volunteers.
- Wiltec, Inc. of Antioch, California, deployed surface street traffic counters.
- Caltrans provided freeway weigh-in-motion data.
- GeoStats of Atlanta, Georgia, supplied the in-vehicle sensors (GeoLoggers) and performed initial data processing and quality assurance.
- South Coast Air Quality Management District provided continuous emissions monitoring systems data.

For More Information

For more information, please visit the ARB's web sites for "weekend effect" and air pollution research.

www.arb.ca.gov/aqd/weekendeffect/weekendeffect.htm

www.arb.ca.gov/research/apr/past/atmospheric.htm

A copy of the final report may be downloaded from the following location:

www.arb.ca.gov/research/abstracts/00-305.htm

